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A FULLY AUTOMATED STAGE FOR OPTICAL

WAVEGUIDE MEASUREMENTS

AD-A273 042



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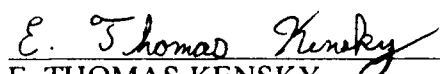
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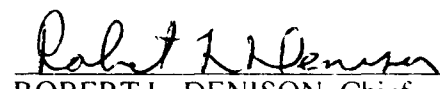
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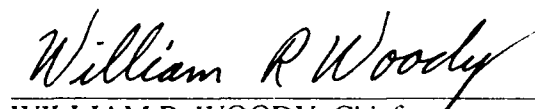
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TABLE OF CONTENTS

SECTION	PAGE
1.0 INTRODUCTION	1
2.0 EXPERIMENTAL BACKGROUND	3
2.1 THE OUT-OF-PLANE TECHNIQUE	3
2.2 THE THREE-PRISM TECHNIQUE	5
3.0 SYSTEM REQUIREMENTS	8
3.1 SPECIFIC REQUIREMENTS	8
4.0 EXPERIMENTAL APPARATUS	11
5.0 SYSTEM DESIGN	14
5.1 MECHANICAL HARDWARE	14
5.1.1 THE RAIL TABLE	14
5.1.2 THE BASE PLATE	15
5.1.3 THE INPUT, OUTPUT, AND MEASUREMENT ARMS	17
5.2 ELECTRONICS AND OPTICS	19
5.2.1 PRISMS AND DETECTORS	20
5.2.2 THE LOAD CELLS	25
5.2.3 THE MEASUREMENT STEPPER MOTOR	27
6.0 EXPERIMENTAL RESULTS	30
7.0 REFERENCES	32
APPENDIX A - ELECTRONIC SCHEMATICS	33
APPENDIX B - MECHANICAL DRAWINGS	37
APPENDIX C - SOFTWARE LISTING	84

LIST OF ILLUSTRATIONS

FIGURE		PAGE
1	Out-of-Plane Scattering Technique Schematic	4
2	Three-Prism Measurement Technique Schematic	6
3	Overall Waveguide Measurement System Schematic	12
4	Photograph of the Waveguide Stage	15
5	The Waveguide Stage Base Plate	16
6	The Input/Output Arm	17
7	Input/Output Arm Schematic	18
8	Prism Holder and Prism	20
9	Three-Prism Detector Holder Arrangement	22
10	Out-of-Plane Detector Holder Arrangement	22
11	Detector Electronics	24
12	Load Cell Electronics	26
13	Custom Interface Electronics	28
14	Three-Inch Sample Measurements	31
15	Two-Inch Sample Measurement	31
16	Load Cells and Detectors Schematic	33
17	Load Cells/Detectors Printed Circuit Board	34
18	Measurement Arm Stepper Motor Interface	35
19	Meas. Arm Stepper Motor Printed Circuit Board	36
20	Base Plate Top View	37
21	Base Plate Side View	38
22	Base Plate End View	39
23	Base Plate Isometric View	40
24	Slide Bracket B I Top View	41

25	Slide Bracket B I Side View	42
26	Slide Bracket B I Front View	43
27	Slide Bracket B I Isometric View	44
28	Slide Bracket B II Top View	45
29	Slide Bracket B II Front View	46
30	Slide Bracket B II End View	47
31	Slide Bracket B II Isometric View	48
32	Slide Bracket A Top View	49
33	Slide Bracket A Side View	50
34	Slide Bracket A Front View	51
35	Slide Bracket A Isometric View	52
36	Upper Guide Bracket Top View	53
37	Upper Guide Bracket Front View	54
38	Upper Guide Bracket Isometric View	55
39	Lower Guide Bracket Top View	56
40	Lower Guide Bracket Front View	57
41	Lower Guide Bracket Isometric View	58
42	Prism Holder A Top View	59
43	Prism Holder A End View	60
44	Prism Holder A Front View	61
45	Prism Holder A Isometric View	62
46	Prism Holder B Top View	63
47	Prism Holder B End View	64
48	Prism Holder B Front View	65
49	Prism Holder B Isometric View	66
50	Detector Holder A Top View	67
51	Detector Holder A Side View	68

52	Detector Holder A Isometric View	69
53	Detector Holder B I Top View	70
54	Detector Holder B I End View	71
55	Detector Holder B I Front View	72
56	Detector Holder B I Isometric View	73
57	Detector Holder B II Top View	74
58	Detector Holder B II End View	75
59	Detector Holder B II Front View	76
60	Detector Holder B II Isometric View	77
61	Rods and Caps	78
62	Upper Guide Bracket Assembly	79
63	Slide Bracket Assembly	80
64	Slide Bracket B Assembly	81
65	Stage Assembly Exploded View	82
66	Bracket Assembly	83

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1.0 INTRODUCTION

Nonlinear optical (NLO) materials are becoming increasingly important to the Air Force, and their expanding use in future systems is inevitable. Applications ranging from communications and optical computing to lasers and laser hardening will all be affected by the development of these materials. Because of this need, basic research and development of these materials are extremely important. Within the Materials Directorate of Wright Laboratory, the Electronic and Optical Materials Branch (WL/MLPO) is performing basic R&D in various areas of nonlinear optical materials. Central to this research is the measurement of the optical properties of these materials.

In order to apply these materials to device and systems, it is important to understand how they behave under the influence of various forces and conditions. These include applied voltages and currents, incident electromagnetic radiation and temperature changes. How they behave under these various conditions can be either useful or detrimental depending on the application. In the case of optical transmission, changes in material properties due to applied voltage are useful for applications where modulation is important. On the other hand, changes in characteristics due to temperature fluctuations can be detrimental when operating in harsh environments. Various methods and techniques have been developed to characterize these materials and predict their behavior in a wide variety of applications.

One important parameter of NLO materials is the attenuation of light. High loss materials can be useful for filtering applications especially when the loss is wavelength dependent. Low loss materials are very useful for transparent window applications and waveguiding. In addition, knowing the loss of a material can help determine the nature of its structure.

The losses in NLO materials can occur from many sources. For guided light structures, these include scattering due to bulk and surface defects and absorption due to resonance, losses due to substrate coupling and losses from irregularities in the interface between the guiding layer and the substrate. There are various methods that can be used to measure these losses and two of the primary methods used in WL/MLPO involve measuring the propagation loss of planar waveguides fabricated from the material being tested. This report describes the design and implementation of a fully automated waveguide stage that allows the measurement of these propagation losses.

2.0 EXPERIMENTAL BACKGROUND

Two techniques used in WL/MLPO for measuring the propagation loss in planar waveguides are the out-of-plane scattering technique¹ and the three-prism measurement technique². These two techniques are similar in their measurement method and their geometrical requirements. Both employ channel or planar waveguides, and in both, the relative intensity of light is measured at points along the propagation path. In the out-of-plane technique, the relative intensity of the light scattered perpendicular to the plane of propagation is measured at many points along the guide, while in the three-prism method, guided light is coupled out from the waveguide at various points and its intensity is measured. In order to understand the design of the waveguide stage, it is useful to explore the experimental basis of these two techniques.

2.1 THE OUT-OF-PLANE TECHNIQUE

The out-of-plane scattering technique (graphically shown in Figure 1) is primarily used to measure waveguides with propagation losses higher than about 1 dB/cm. When using the visible wavelengths, these waveguides usually show a characteristic bright streak along the guide path. This is indicative of light being scattered from confined waveguide modes from scattering centers within the waveguide layer and at the interfaces. The intensity of the scattered light can be measured using a detector which is suspended above the streak and is moved parallel to the streak.

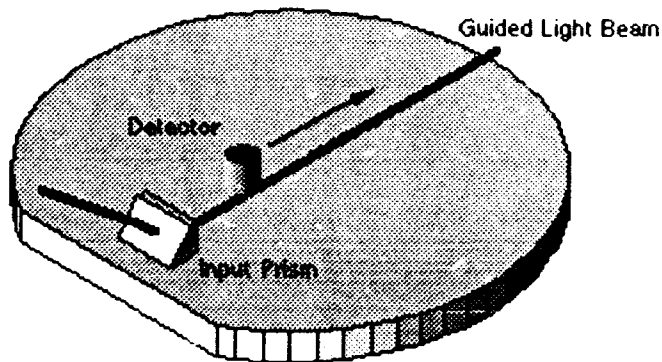


FIGURE 1 - Out-of-Plane Scattering Technique Schematic

The scattering centers are assumed to be homogeneous and evenly distributed over the length of the waveguide. This is required if a reasonable comparison is to be made of the scattered light intensity at various points along the propagation path. Inhomogeneities in the distribution of scattering centers cause substantial nonuniformities in the scattered light intensity along the direction of propagation. The result is an unreliable figure for propagation loss for the waveguide.

The actual propagation loss for this technique is calculated using Beer's Law. This is given in equation 1. The loss value is obtained by taking the slope of the log of the intensities (this is α in equation 1) between the initial intensity reading and each subsequent reading of the scattered output intensities at points along the guide path.

$$I(z) = I_0 e^{-\alpha z} \quad (1)$$

$$\begin{aligned} \text{Propagation Loss in dB/cm} &= 10 \log \frac{I(z)}{I_0} \\ &= 10 \log \frac{I_0 e^{-\alpha z}}{I_0} = 10 \log(e^{-\alpha z}) = -10\alpha z \log(e) = -10\alpha z \frac{\ln(e)}{\ln(10)} \\ &= -4.343\alpha z \end{aligned}$$

Where

I_0 = relative out-scattered intensity at the first measured point

$I(z)$ = relative out-scattered intensity at point z along the path

α is the attenuation factor

z is the distance in cm (set to 1 cm)

α is determined by a least-squares curve fit or by plotting the data (i.e. $I(z)$) on a log scale and taking the slope.

A distinct advantage of this technique is the ability to measure losses in "softer" waveguide materials such as polymers and organics. Since the detector never comes in contact with the waveguide the surface is never disturbed. This is not the case with the three-prism technique.

2.2 THE THREE-PRISM TECHNIQUE

The three-prism technique, as the name implies, employs three prisms to couple light into and out of a waveguide. This is shown in Figure 2. The first prism, called the input prism, couples light energy into the waveguide. The other two prisms, called the measurement and exit prisms, respectively, are used in conjunction with the appropriate detectors to measure the intensity of the out-coupled light along the propagation path of the waveguide. This technique works well when the waveguides are sufficiently long (1-2 inches) and it is uniquely suited for measurements where the losses for the materials are relatively low (<1 dB/cm).

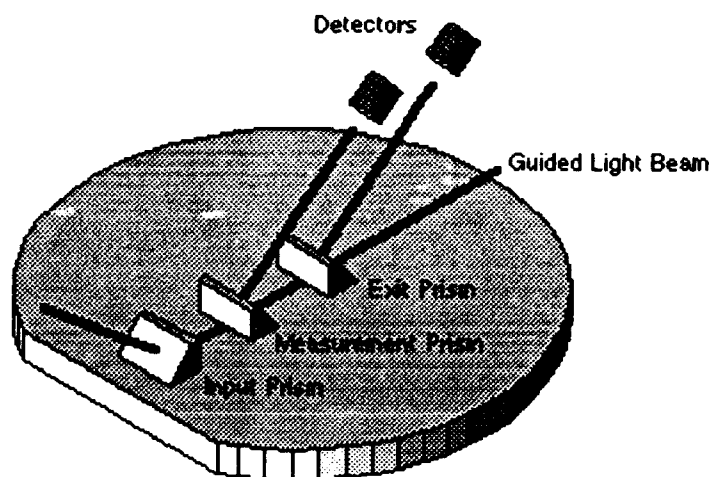


FIGURE 2 - Three-Prism Measurement Technique Schematic

The three-prism measurement is performed by using the input prism to couple light into the waveguide. The relative intensity of the light inside the guided path is then measured by using the measurement and exit prisms. First, a quiescent light intensity is measured using the exit prism with the measurement prism off of the waveguide. This value, P_{e0} , is used as the reference for all measurements taken along the points of the guide path. To make the loss measurements, the measurement prism is pressed onto the waveguide at equally spaced points along the guide path and intensity readings from both the measurement (P_m) and exit prisms (P_e) are taken. These values and P_{e0} are used to calculate the relative decrease in intensity at each point along the waveguide. The loss in dB/cm given in equation 2, is then calculated by taking the slope of these calculated values when plotted on a log scale. The advantage of using the exit prism is that it eliminates the need to know the coupling coefficient of the measurement prism.

3.0 SYSTEM REQUIREMENTS

An automated system that can be used to make out-of-plane and three-prism loss measurements for optical waveguides must meet certain requirements. For example, there are certain geometric requirements that affect the accuracy of the measurements. One of these is the need for a known reference for distance measurements. In addition, accurate light intensity measurements have certain conditions that must be met. In the case of the out-of-plane measurement, only a narrow portion of the guiding streak can be measured at each point if an accurate loss measurement is to be made. These requirements necessarily affect the design of the measurement system, and they will be explored more fully in the following sections.

3.1 SPECIFIC REQUIREMENTS

There are many geometrical, electrical, and optical requirements for a successful waveguide stage system. First, a planar surface is required to support waveguide substrates. This is needed to prevent damage to the wafers when pressure is applied from the coupling prisms. Secondly, motion along the waveguide length must be strictly controlled. The travel path must be parallel to the direction of the propagation path. The positions along the path where measurements are to be taken must be accurately known, and they must be repeatable. This is necessary if multiple measurements of the same sample are to be taken to verify operation. In addition, smooth, equal pressure must be applied to the prisms when coupling to the waveguide. This is necessary to ensure proper coupling and to prevent damage to the wafer.

$$\text{Propagation Loss in dB/cm} = -4.343\alpha z \quad (2)$$

Where

$I(z)$ = ratio of out-coupled light from the exit and measurement prisms

$$\frac{P_m P_{e0}}{P_{e0} - P_e} = e^{-\alpha z}$$

α is the attenuation factor

z is the distance in cm (set to 1 cm)

P_m is the measurement prism intensity

P_e is the exit prism intensity

P_{e0} is the quiescent exit prism intensity (measurement prism off the waveguide)

α is determined by a least-squares curve fit of $I(z)$ or by plotting the data (i.e. $I(z)$) on a log scale and taking the slope.

The three-prism method, as in the case of the out-of-plane method, also relies on a certain level of uniformity in the waveguide. Accurate loss measurements over a distance still require a uniform distribution of loss centers. However, nonuniformities in the waveguides such as bright spots are easily detectable with this technique, and the information obtained can be useful in determining the overall physical quality of the waveguide. The main disadvantage of this technique is that it requires "harder" waveguide materials. This is due to the fact that the prisms must be pressed onto the surface of the guide in order to obtain sufficient contact to allow coupling. Softer materials may be damaged by this technique, and any data taken on a damaged surface would be useless.

Both of these techniques employ planar waveguides and make intensity measurements at points along the guide path. These commonalities lend themselves to a single test setup that could easily be changed to accommodate either method.

Interchangeability is also an issue. The system must be able to be converted from the three-prism technique to the out-of-plane scattering technique with a minimum of effort. To meet this requirement, parts of the system must be designed to allow easy disassembly and reassembly without affecting the ultimate accuracy and repeatability of the system. In addition, all parts that are not removable must be designed to allow various attachments to be added with ease. This accommodates such things as various size prisms and detectors.

The electrical and optical requirements are also numerous. For example, coupling prisms must have as much available space as possible for launching light into and out of the waveguide. This is required in order to facilitate as many coupling angles as possible for a wide variety of guiding modes. Additionally, the detectors used for measuring the out-coupled or out-scattered light must be able to capture light at any of the out-coupling angles or at any position along the waveguide. Another requirement is the need to minimize backscattered light detection. The detectors must be designed to eliminate unwanted light from input coupling and from the surroundings. This light adversely affects the measurements.

Although not necessary for the three-prism technique, it is advantageous to know the force which is being applied to the coupling prisms. This allows repeatability in coupling pressure and can also be used to prevent excessive force from being applied to sensitive waveguides. This is best accomplished through the use of force detectors such as load cells.

A final requirement for a waveguide stage system is computer control for movement and data acquisition. In the modern laboratory setting, this is essential. These measurements are tedious and time consuming. Doing these types of measurements "by hand" also greatly increases the chance for errors. Computer control of all motion and data acquisition yields vastly improved accuracy and

repeatability while greatly reducing the chance for error. In addition, allowing a computer to take control frees the researcher for other more important tasks.

The waveguide stage measurement system has been designed to meet these requirements by combining commercially available equipment and custom designed parts.

4.0 EXPERIMENTAL APPARATUS

An overall schematic of the waveguide measurement system is shown in Figure 3. The heart of the system is the waveguide stage and its associated electronic and mechanical components. These are explained fully in Section 5. The remaining supporting equipment consists of the computer and electronic equipment necessary to take data from the waveguide stage.

The data acquisition portion of the waveguide measurement system is designed around a Hewlett Packard 9000 330 MMA computer using the HP BASIC 5.0 programming language. This allows easy programming for automated data acquisition. In addition, this computer is connected to a local area network which allows easy transfer of data to other systems more suitable for analysis and presentation.

The HP computer controls various external equipment necessary for supplying stimulus and acquiring response to and from the waveguide stage. In order to measure optical response from detectors on the waveguide stage as well as pressure readings from load cells, a Hewlett Packard HP3457A Digital Multimeter (DMM) is used. This DMM has an HP44492 10-channel Relay Input Card option that allows the DMM to be switched between 1-of-10 input channels. This allows a single DMM to be used to measure all signals from the waveguide stage.

In order to drive the rail table portion of the waveguide stage (rail table explained in Section 5), a Daedal MC 2000/MD 23 Linear Motion Controller/NEMA Motor Driver is employed. This combination allows accurate computer control and measurement of the out-coupling position of the measurement prism of the waveguide stage.

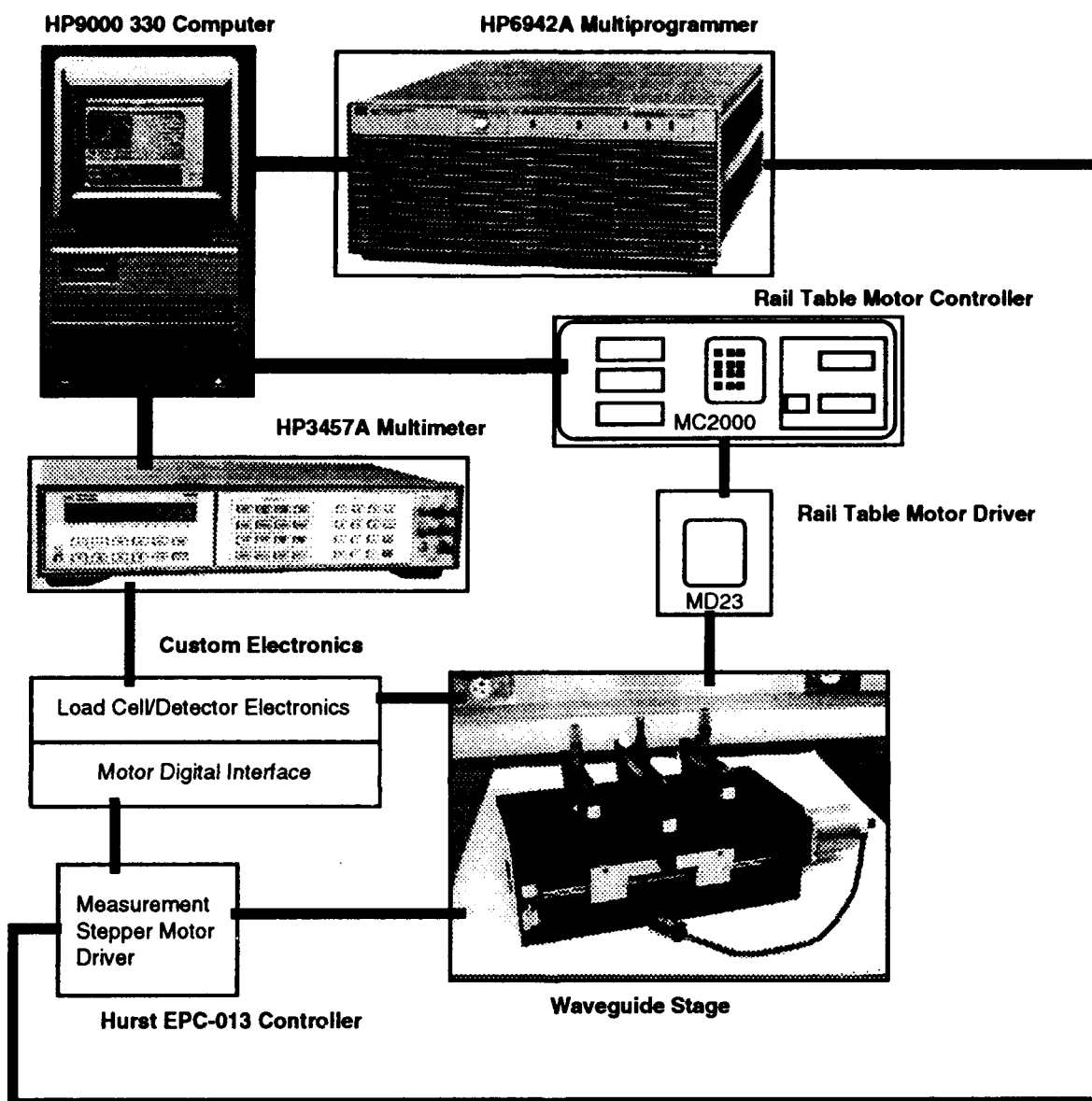


FIGURE 3 - Overall Waveguide Measurement System Schematic

Also employed in the waveguide measurement system is an HP6942A Multiprogrammer. This device is a multipurpose card cage that allows various special purpose cards such as relay cards or D/A converter cards to be accessed by a computer. As used in this system, an HP69735 Pulse Train/Stepper Motor

card is used in the multiprogrammer to supply pulses to a Hurst stepper motor to control the measurement arm of the waveguide stage (see Section 5).

The rest of the system is comprised of the custom mechanics and electronics required to interface between the DMM, the Multiprogrammer and the waveguide stage. These custom components provide measurement arm drive and I/O signal condition necessary for data acquisition. Their purpose and function is explained fully in Section 5.

5.0 SYSTEM DESIGN

The system surrounding the waveguide stage (Figure 4) contains mechanical hardware, electronics and optics, and computer software. This is a mixture of commercial and custom components, and each of these will be discussed in the context of full system operation.

5.1 MECHANICAL HARDWARE

The mechanical hardware of the waveguide is comprised of a commercially available rail table to which custom-designed components have been added. The custom components are designed for specific application to three-prism or out-of-plane scattering loss measurements. The main components are the stage base plate, the input and output arms and the measurement arm. All parts are machined from aluminum, and they are black-anodized for use in laser environments.

5.1.1 THE RAIL TABLE

The rail table (Daedal Model 506041S-LH) has 4 inches of linear travel and is equipped with a five-pitch double nut ball screw mechanism to minimize backlash. The rail table is driven by a standard NEMA 23 frame stepper motor having 10,000 steps per revolution of rotational resolution. This allows the rail table to have ± 0.0002 -inch position repeatability and ± 0.00025 in/in position accuracy. The NEMA 23 motor is driven by a Daedal single axis motion controller complete with IEEE-488 interface (Daedal Model MC 2000). This provides complete computer control of the motion of the rail table including the speed,

acceleration/deceleration rate and the step resolution between measurements positions.

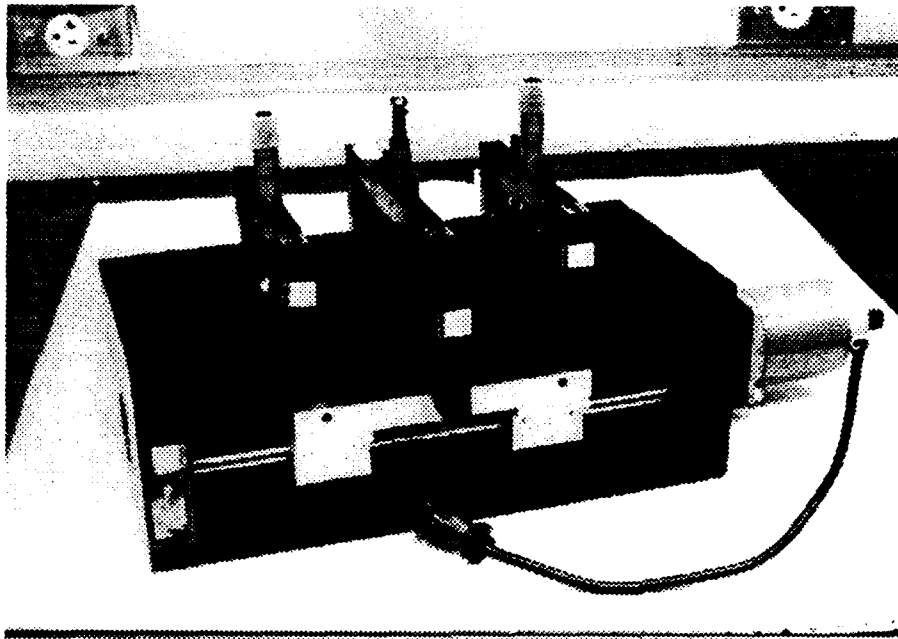


FIGURE 4 - Photograph of the Waveguide Stage

5.1.2 THE BASE PLATE

The base plate for the waveguide stage is shown in Figure 5. The base plate serves as the mounting seat for the waveguide substrates and as a mount for the input and output arms. The base plate is mounted to the rail table using $\frac{1}{4}$ - 20 NC screws. The plate has been precision machined for flatness and it is aligned to the rail table using set pins and offset mounting holes for the $\frac{1}{4}$ - 20 screws. This ensures that the base plate stays aligned parallel to the rail table and that it can only be mounted with one unique orientation in the event disassembly is required.

In order to ensure maximum flatness, the rail table was machined "true" at the time of manufacture of the base plate.

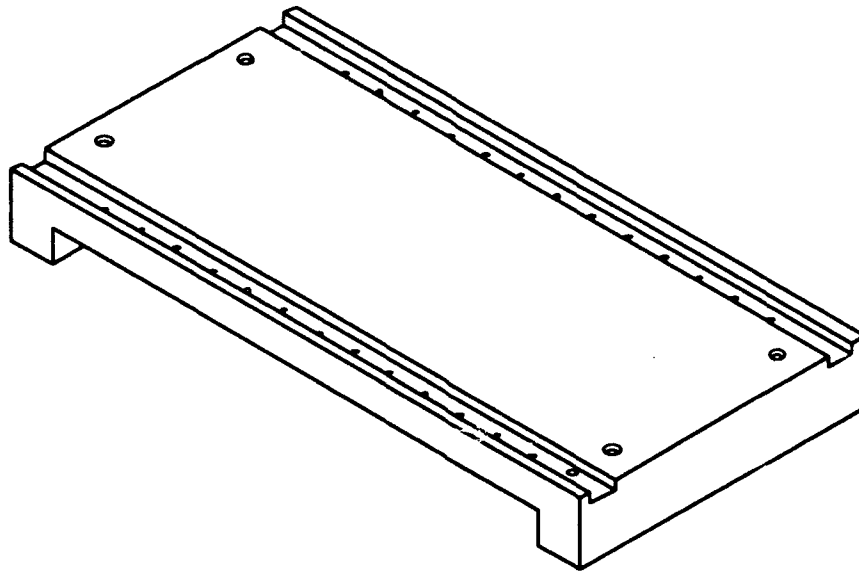


FIGURE 5 - The Waveguide Stage Base Plate

The base plate has a set of 8-32 NC mounting holes that are equally spaced along two $\frac{1}{4}$ inch troughs that run along each side of the base plate. These troughs hold the input and output arm mechanisms and allow the arms to be positioned and secured anywhere along the length of the base plate. This allows maximum flexibility while maintaining parallel positioning with respect to the sides of the base plate.

The base plate is raised up from the surface of the rail table $\frac{3}{4}$ inch to allow the measurement arm to be mounted to the rail table. This in turn allows the measurement arms to move along the length of the base plate with the accuracy of the rail table.

5.1.3 THE INPUT, OUTPUT, AND MEASUREMENT ARMS

The input and output arms, shown in Figure 6, are identical in construction. Each arm is positioned over the surface of the waveguiding substrate. The input arm is placed at the front of the waveguide, and it is used to launch light into the guide. The output arm is placed at the end of the guide, and it is used to measure the exit intensity of the light exiting from the waveguide during three-prism measurements. It is not used for out-of-plane measurements and can be removed.

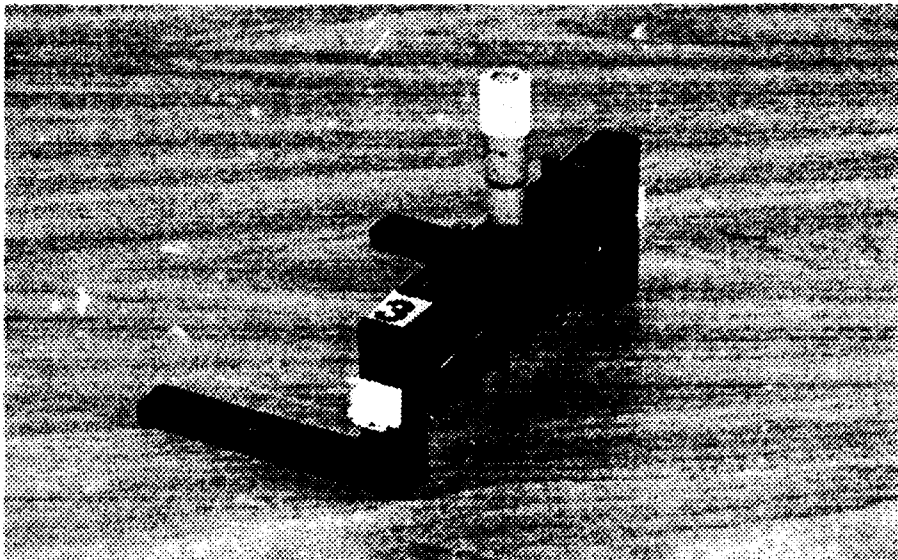


FIGURE 6 - The Input/Output Arm

The input/output arms are comprised of various moving parts that facilitate proper placement of the prisms onto the waveguide substrate. This is shown in Figure 7. Each arm is identical with the exception of a removable detector attachment for the output arm.

The operation of the input/output arm is straightforward. A set of steel rods is used to control the motion of the various moving parts of the arm. Referring to

Figure 7, the two outer steel rods are firmly press-fit into the slide bracket. This slide bracket slip-fits into the base plate and is screwed down into position over the waveguide substrate. The two inner steel rods are press-fit into the upper guide bracket and are allowed to slip freely through the slide bracket. The lower guide bracket has a prism attachment or and/or a detector attachment (depending on which measurement technique is being used), and it is also allowed to slip freely over the two inner steel rods. The whole mechanism is raised and lowered onto the waveguide substrate by a micrometer screw assembly and two springs located on the outer steel rods.

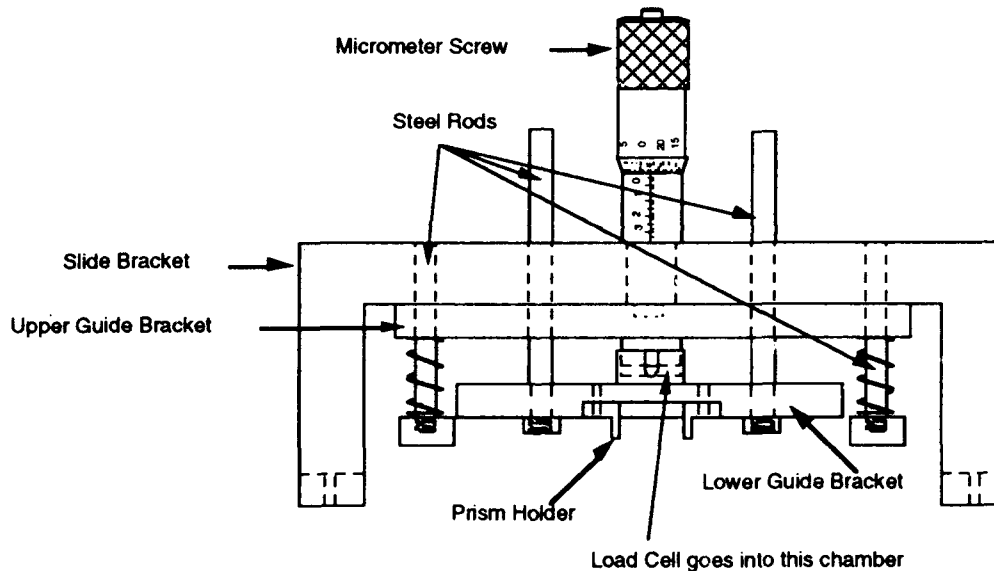


FIGURE 7 - Input/Output Arm Schematic

A unique feature of the arms is the use of compression load cells in the axis of applied force of the prisms. These load cells (Sensotec Model 13, AL322BN) are placed in all three arms of the waveguide stage, and they are located in the cup of the lower guide bracket. Due to the design of the arms, the load cell will only

measure the force being applied to the prisms. This is extremely useful when the stage is being used to measure polymer and other soft material waveguides. Excessive pressure can damage these types of guides making the measured data useless. In addition, these load cells allow the coupling pressure to be maintained and duplicated between measurements on the same sample and from sample to sample.

The measurement arm is identical to the input/output arms in construction and operation with two exceptions. First, the measurement arm does not have a slide bracket but rather has a two-piece bracket that attaches to the rail table instead of the base plate. This allows the measurement arm to be moved along the waveguide path to make measurements with the positioning accuracy of the rail table. Second, the micrometer screw assembly of the measurement arm is driven by a computer-controlled stepper motor. This allows complete control of the data acquisition by software programming.

Complete drawings for the input/output and measurement arms, as well as all other custom-designed mechanical parts, can be found in the Appendices.

5.2 ELECTRONICS AND OPTICS

The electronics and optics for the waveguide stage consist of the voltage references, amplifiers, prisms, etc. that allow the actual acquisition of the data pertaining to the waveguide under test. This can be classified into three groups: (1) the prisms and detectors and their associated electronics, (2) the load cells and their electronics, and (3) the measurement stepper motor. The first two are custom implementations, and the last is a commercially available unit.

5.2.1 PRISMS AND DETECTORS

The prisms are the only strictly optical component for the stage and their operational requirements are mechanical in nature, however, their discussion with the detectors is warranted. As mentioned previously, the prisms must be applied to the waveguide with a steady and even pressure. To accomplish this, a special prism holder was developed. A representative holder is shown in Figure 8. These holders come in various sizes to accommodate various size prisms.

The prism holders are interchangeable and attach to the lower guide brackets using 2-56 NC screws. This allows all holders to fit into the lower guide bracket making it very convenient to change from one type of prism to the other.

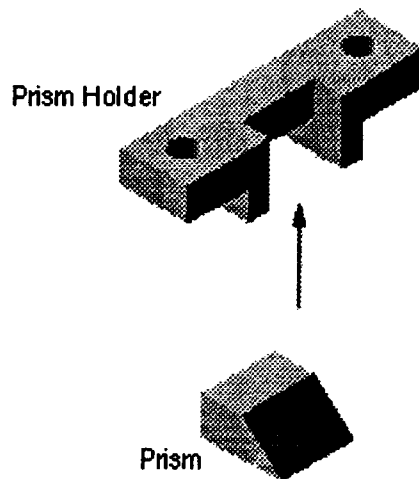


FIGURE 8 - Prism Holder and Prism

The holders were originally lined entirely on the inside with felt. This provided both a friction grip as well as protection from cracking for the prisms. However, the felt placed on the inside top produced excessive cushioning to the

prism when pressure was applied. This caused a classic exponential relaxation in the pressure applied to the prism as the felt continued to compress. This made accurate pressure measurements with the load cells very difficult. To remedy this problem, the felt on the inside top was replaced with thin teflon sheeting. This allowed protection of the prism top surface while greatly reducing the compression relaxation.

The detectors associated with the three-prism and the out-of-plane techniques have both mechanical and electronic fixturing. The physical setup for the detectors is different for each technique. For the out-of-plane technique there is only one detector and it must be suspended over the waveguide on the measurement arm. For the three-prism technique, two detectors are required, one for the measurement arm and one for the output arm. These detectors must be placed as close as possible to the prisms on each arm in order to capture the exiting light regardless of the out-coupling angle. In addition, the fixturing for mounting the detectors for both techniques must allow easy interchangeability.

The configurations for detector mounting for both techniques are shown in Figures 9 and 10. For the three-prism technique, the detectors are fixed to an angled mounting bracket using silicone adhesive. The bracket is then attached to the lower guide bracket using the same 2-56 NC screws that attach the prism holder. For the out-of-plane technique, a special detector mount was fabricated that attaches to the lower guide bracket in place of the prism holder on the measurement arm. This holder is a two-piece unit and the detector fits in between the pieces. A small slit in the bottom piece that is positioned over the detector is the input for the scattered light from the waveguide.

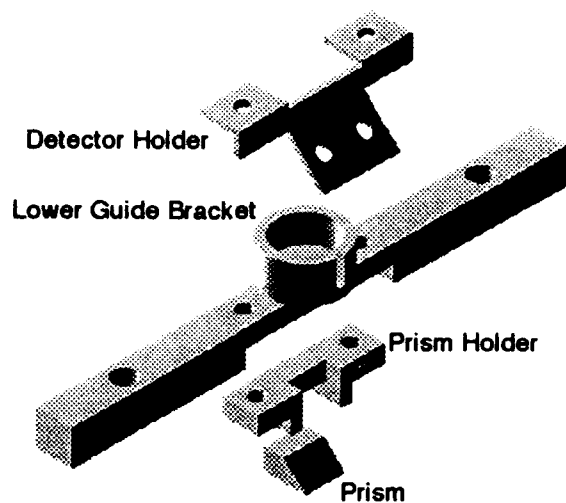


FIGURE 9 - Three-Prism Detector Holder Arrangement

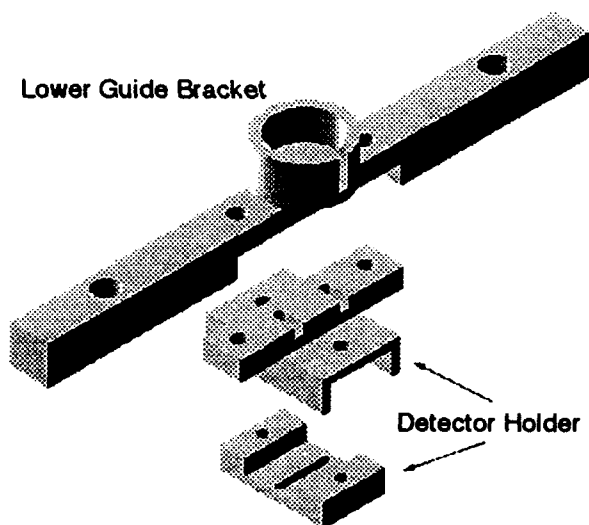


FIGURE 10 - Out-of-Plane Detector Holder Arrangement

The detectors used for both techniques are Hamamatsu model S1227-66BQ silicon photodiodes. These detectors have a thin, rectangular shape that is ideally suited for this application. The overall size of these detectors is 10 mm x 9 mm x 2

mm with an active detector area of 33 mm². The S1227-66BQ has a response from 190 nm to 1000 nm with a peak at 720 nm and a typical radiant sensitivity of 0.35 A/W at the peak wavelength³.

The electronic circuitry for the detectors is shown in Figure 11. The detectors form part of a variable gain current-to-voltage converter. The gain for each amplifier is controlled by a series of resistors connected to a rotary switch. This allows gain adjustment for different light intensity levels. The current generated in the detector due to incident light is converted to a voltage at the output of the operational amplifier (op-amp) according to equation 3.

$$V_o = -I_r R_f \quad \text{volts} \quad (3)$$

where
 I_r = total photodiode current in amps
 R_f = feedback resistor in ohms

The photocurrent, I_r , for the S1227-66BQ is given in equation 4⁴. The second and third terms of this equation can be ignored because the series resistance of the photodiode is small ($R_s < 10 \, \Omega$) and because the shunt resistance is large ($R_{sh} > 10^7 \, \Omega$)⁵. This makes the current and, thus, the output voltage from the op-amp, very nearly directly proportional to the light intensity striking the detector.

$$I_r = I_L - I_s \left(e^{\frac{qI_r R_s}{kT}} - 1 \right) - \frac{I_r R_s}{R_{sh}} \quad (4)$$

where
 I_r = total current pulled through the photodiode
 I_L = Current due to the incident light on the detector
 I_s = photodiode reverse saturation current
 R_s = photodiode series resistance
 R_{sh} = photodiode shunt resistance
 q = electronic charge
 k = Boltzmann's constant
 T = Absolute temperature of the photodiode

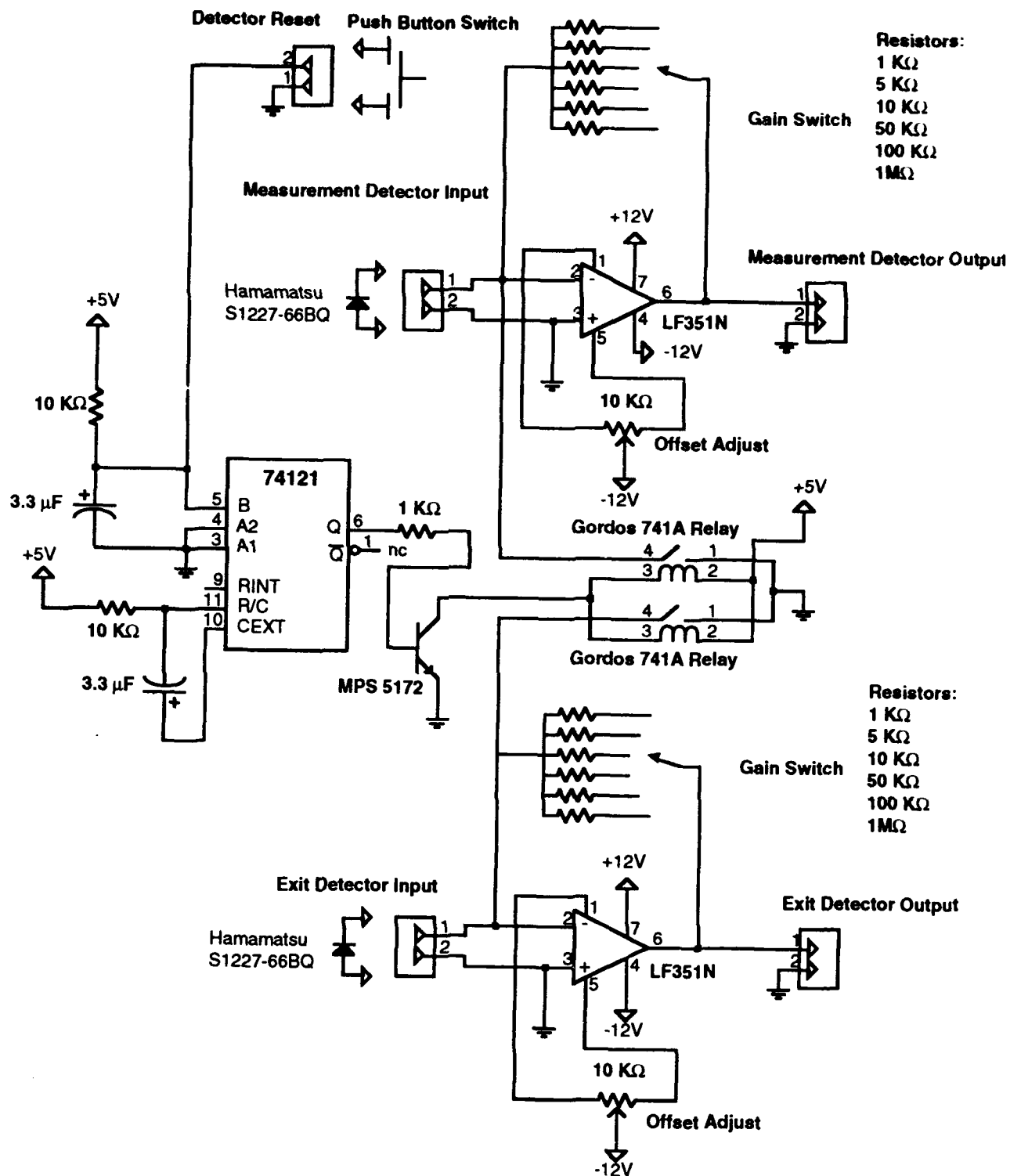


FIGURE 11 - Detector Electronics

The 74121, the relays and the transistor in the circuit of Figure 11 have been added to prevent latching of the op-amps when the power is first applied to the stage electronics. It has been experimentally determined that the high input impedance of the LF351N, coupled with the low reverse bias current of the photodiodes and the stray capacitance of the cabling connecting the photodiodes to the op-amp, causes a latched and/or oscillating condition. The 74121 is a timed one-shot that shorts the inputs of the op-amps until the power supplies have settled. This allows the op-amps to have a stable reference when the inputs are released which eliminates the latching or oscillating.

5.2.2 THE LOAD CELLS

The load cell signal-conditioning electronics employed in the waveguide stage are shown in Figure 12. Each arm of the waveguide stage has a load cell that measures the pressure being applied to the prisms. These load cells operate in a standard compensated Wheatstone bridge configuration. The bridge is driven by a voltage reference, and the resistance in one of the arms changes as force is applied. This change causes a voltage differential to appear across the bridge that is related to the force that is being applied⁶. This voltage is amplified using a differential amplifier, and the output is available as a measure of the force being applied to the prisms.



26

operational amplifier (LM351N). The zener voltage is adjusted using the potentiometer connected to pin 3. The differential voltage produced by the load cell is amplified by a Burr-Brown INA101CM Instrumentation Amplifier. The gain of this amplifier is set by resistors R1, R2 and R3. This allows precision adjustment of the full scale output of the load cell.

5.2.3 THE MEASUREMENT STEPPER MOTOR

The stepper motor assembly employed to drive the measurement arm is comprised of a commercially available stepper motor mounted on a custom-designed bracket. The motor is a Hurst SAS Series geared stepper motor with a rotation speed of 0.42 rpm providing 600:1 reduction with a typical torque of 200 oz-in. The motor is driven by a Hurst EPC-013 Stepper Motor Controller board. This board provides the drive current for the motor as well as the input/output to allow manual and digital control for the motor. The EPC-013 is interfaced to custom-designed electronics that allows switching between computer control and manual control. Ultimately, the computer control is accomplished through a Hewlett Packard HP6942A Multiprogrammer Interface Pulse Train Stepper Motor Controller card.

The EPC-013 provides inputs that allow control of various aspects of the stepper motor. This card controls the acceleration/deceleration of the motor, the rotation direction, the phase setting (3 or 4) and the run/hold status. In addition, this card has a free running pulse train to allow manual control of the motor and an input for external pulse trains to allow other circuitry to control the motor.

The custom electronics that serves as an interface between the Hewlett Packard multiprogrammer and the EPC-013 is shown in Figure 13. This circuit functions as a data router that allows the user to either control the motor manually

or by the computer. The circuit has two digital data selectors (74157) that allow either pulses from the computer or a pulse train from the EPC-013 to control the motion of the stepper motor. Manual/Computer control is determined by the setting of a DPDT switch connected to the select line of one of the 74157s. Another data selector chooses from either up or down pulses being supplied from the computer. The multiprogrammer pulse train card sends pulses out on one of two lines depending on which rotation direction is desired. These pulses are distinguished by which line is active. A 74123 One Shot is triggered by the pulses and acts as a timer for the select lines to the data selector. This ensures proper pulse routing and duration to the motor driver card.

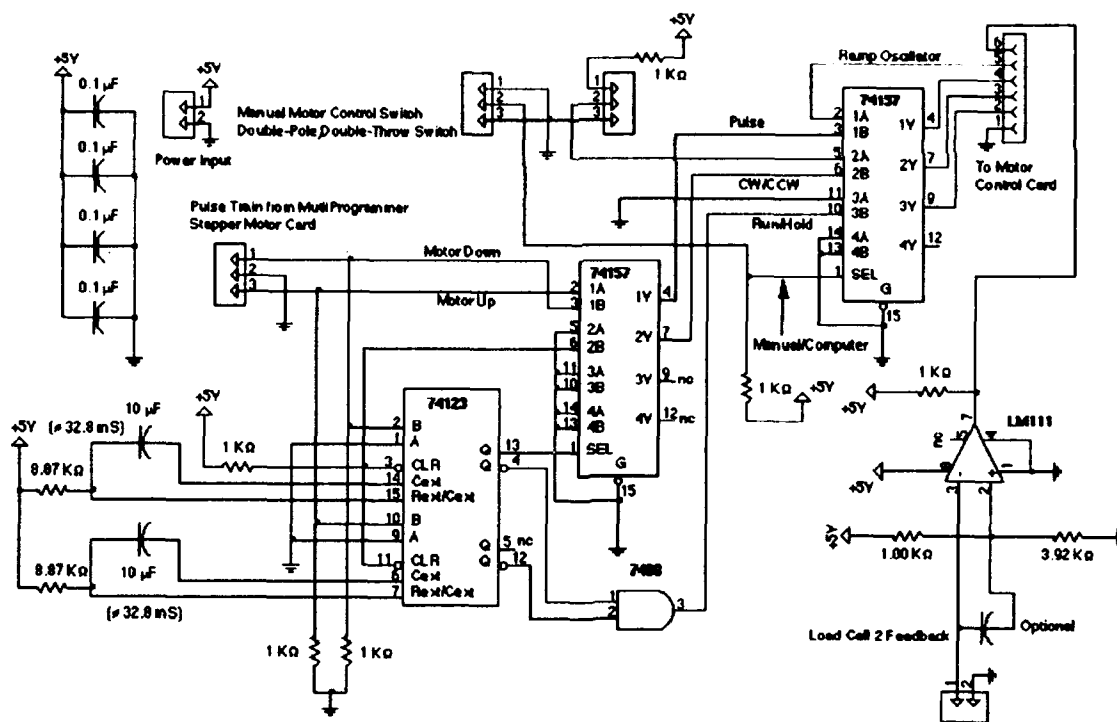


FIGURE 13 - Custom Interface Electronics

This custom interface has two special features. First, manual control automatically overrides computer control. If anything goes wrong, the motor can be controlled or shutdown manually using one of two switches. In addition, a special comparator circuit provides auto-shutdown if the load cell pressure exceeds 40 lbs of force.

6.0 EXPERIMENTAL RESULTS

The operation of the waveguide stage has been verified by the three-prism, the two-prism, and the out-of-plane scattering techniques⁷. Loss measurements using each of the techniques were taken on planar waveguides made from hexafluoro isopropylidene-polybenzoxazole (6F-PBO-1E) on oxidized Si wafers. The waveguides were fabricated by spin coating 1.0- μ -thick layers of 6F-PBO-1E on 1.4- μ -SiO₂ buffer layers on 2- and 3-inch silicon substrates. Loss measurements were taken on a 3-inch sample at a wavelength of $\lambda = 900$ nm using the out-of-plane and the three-prism and techniques for comparison. A 2-inch sample was measured using the two-prism method at a wavelength of $\lambda = 900$ nm to compare losses between samples. The resulting data for all samples were fitted to the Beer's law relationship given in equations 1 and 2. The plots of the data are shown in Figures 14 and 15. The loss for the 3-inch waveguide was found by averaging the loss for the three-prism and the out-of-plane techniques. The loss for the two-inch sample was taken from the data provided by the out-of-plane scattering technique. The average loss for the 3-inch sample was $3.93 \pm .565$ dB/cm and the measured loss for the 2-inch sample was 3.523 dB/cm.

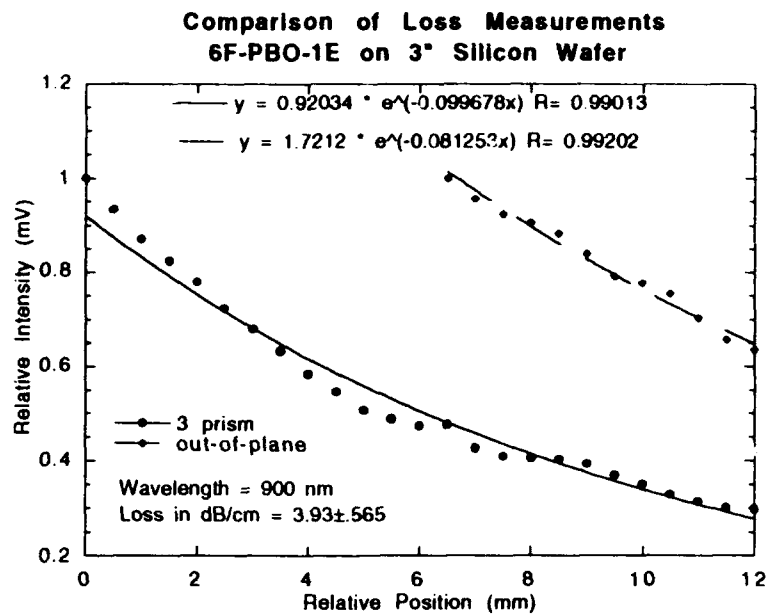


FIGURE 14 - Three-Inch Sample Measurements

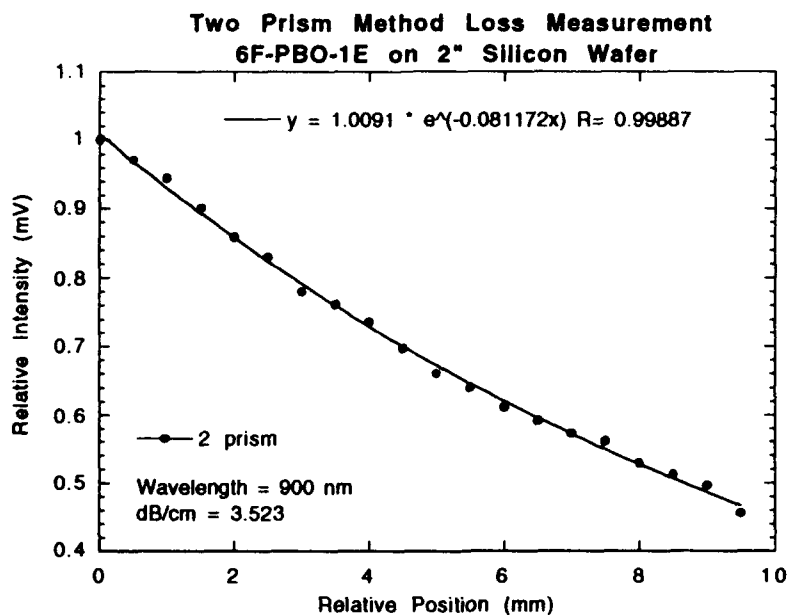


FIGURE 15 - Two-Inch Sample Measurement

7 0 REFERENCES

1. R. G. Hunsperger, Integrated Optics: Theory and Technology, Second edition, Springer-Verlag, Berlin, Heidelberg, New York, Tokyo (1984)
2. Y. H. Won, P. C. Jaussaud, and G. H. Chartier, Appl. Phys. Lett., 37, p269 (1980)
3. Hamamatsu Photodiode Product Catalog CR-3000, pp14-15, (May 1990)
4. Hamamatsu Photodiode Product Catalog CR-3000, p4, (May 1990)
5. Hamamatsu Photodiode Product Catalog CR-3000, p4, (May 1990)
6. Daniel H. Sheingold, ed., Transducer Interfacing Handbook, p16-21, Analog Devices Inc., Norwood MA, 1981
7. Angela L. McPherson, and Jeffery W. Baur, "Guided Wave Loss Measurements for End-capped 6F-Polybenzoxazole," unpublished work

APPENDIX A - ELECTRONIC SCHEMATICS

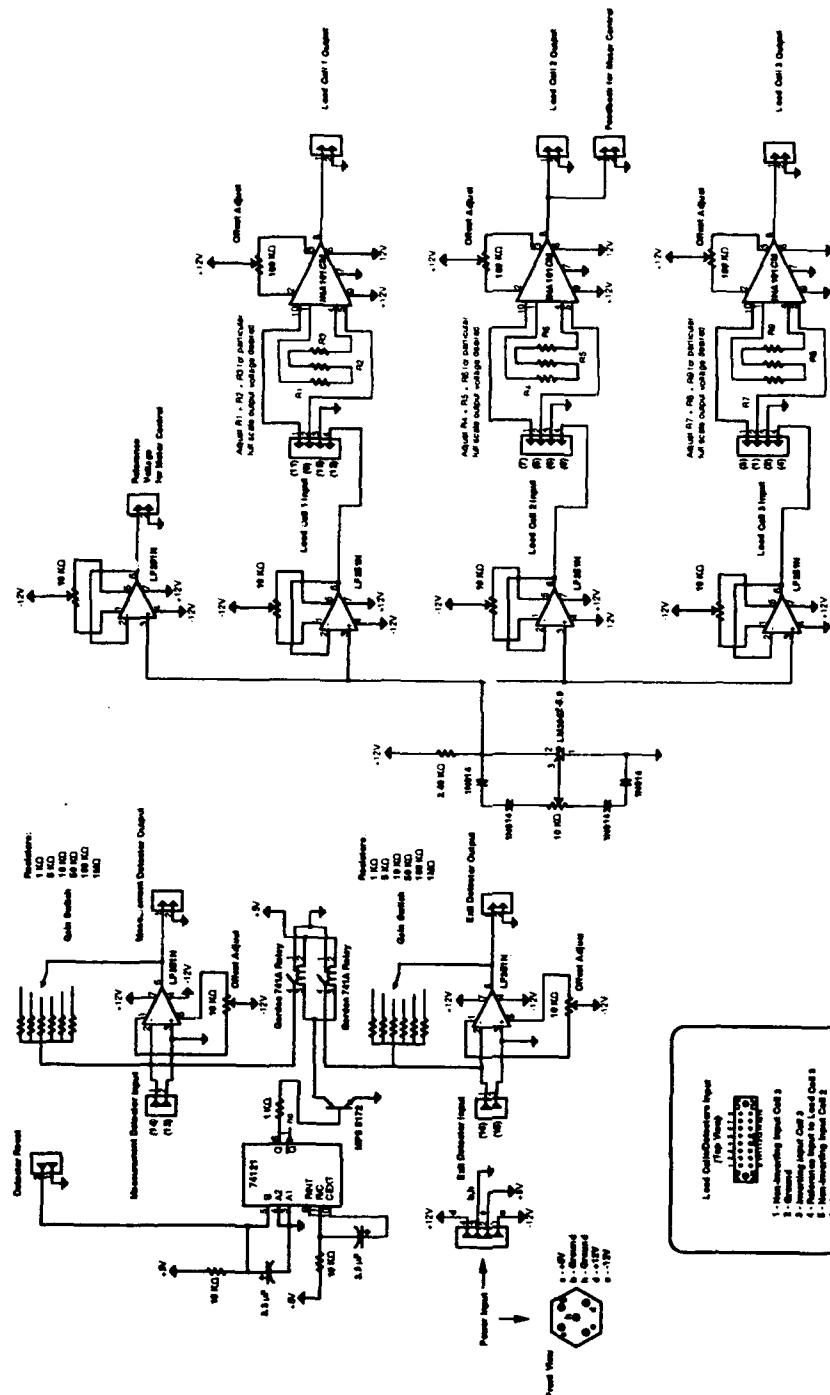
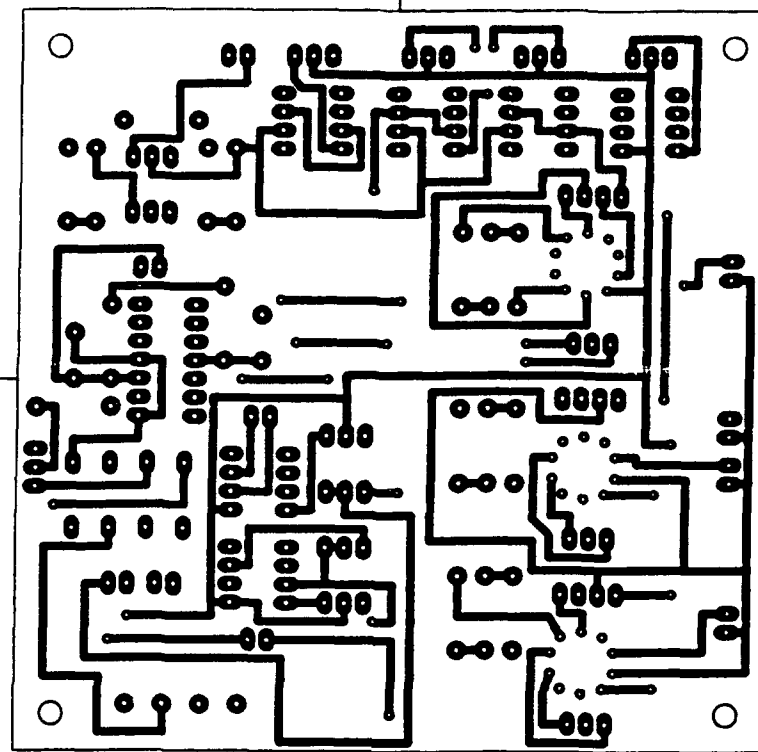
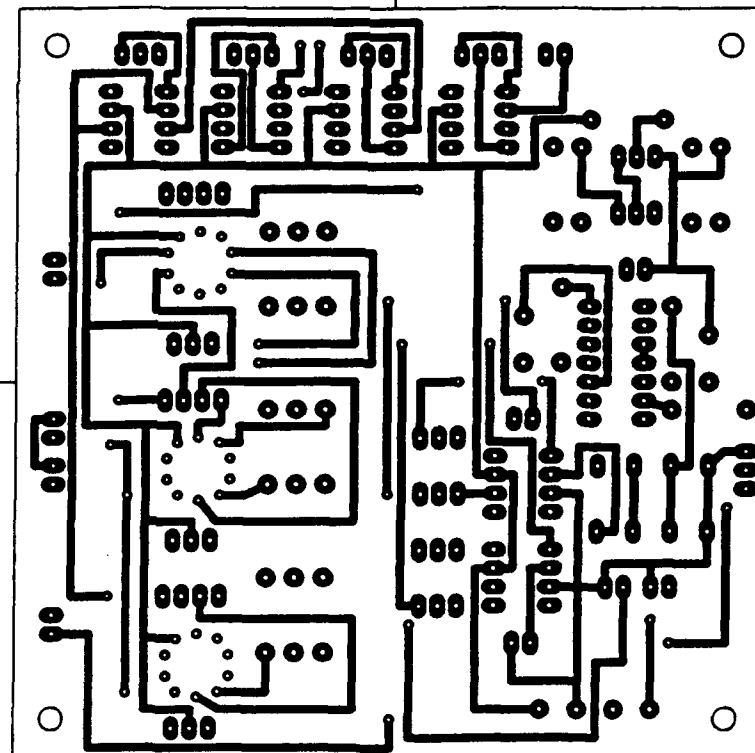


FIGURE 16 - Load Cells and Detectors Schematic



Component Side



Solder Side

FIGURE 17 - Load Cells/Detectors Printed Circuit Board

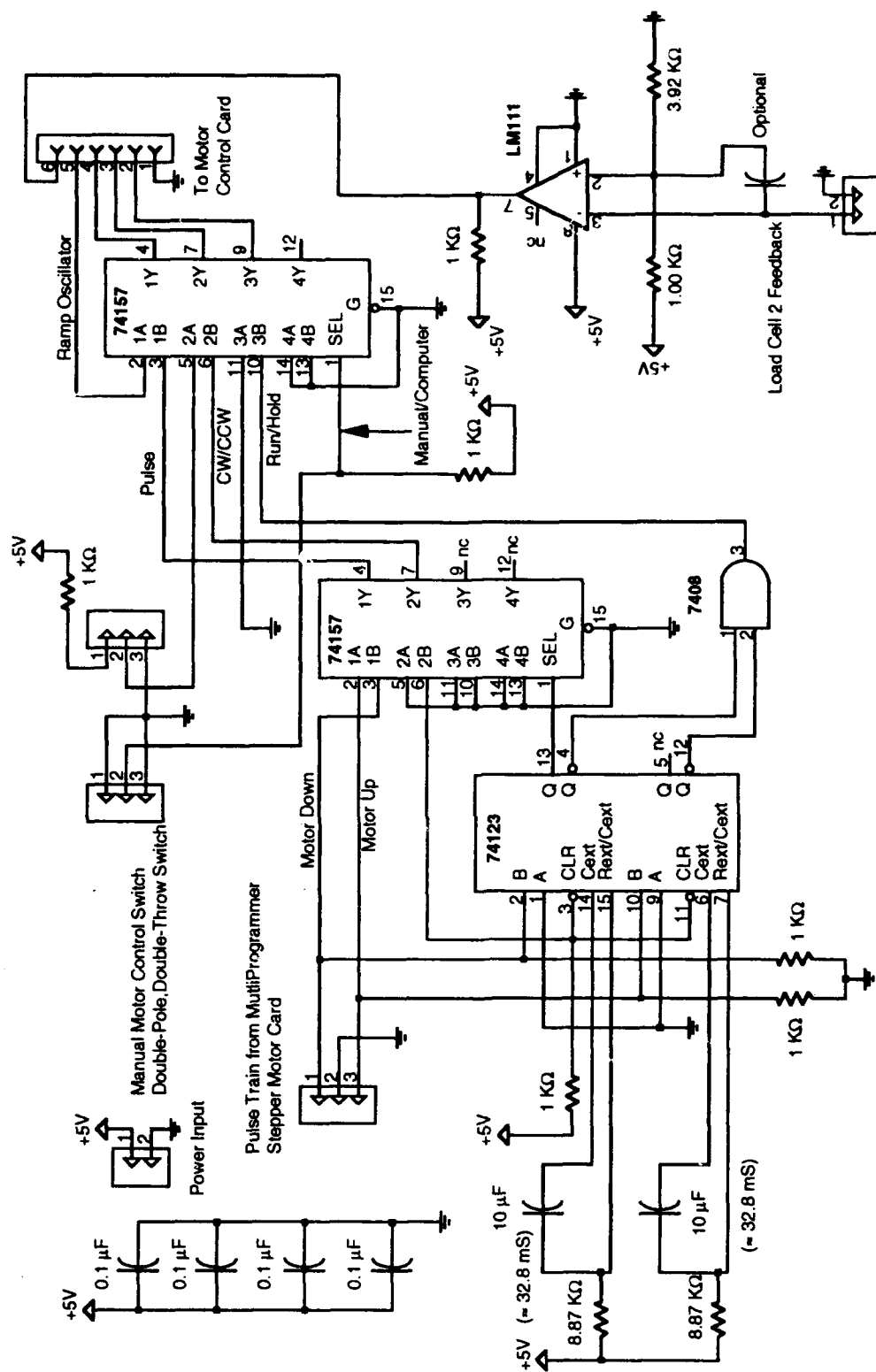
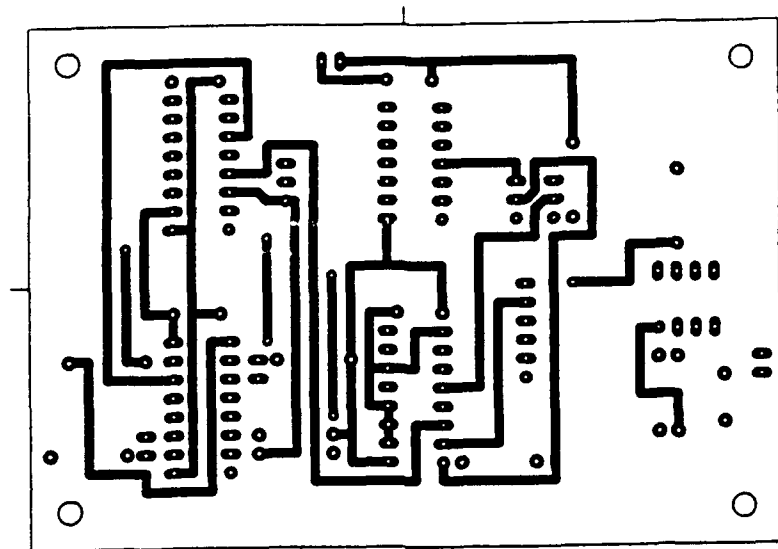
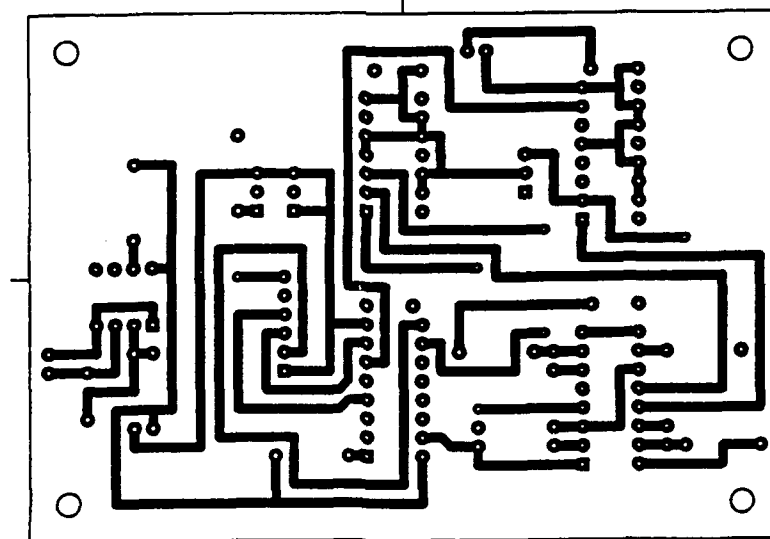


FIGURE 18 - Measurement Arm Stepper Motor Interface



Component Side



Solder Side

FIGURE 19 - Meas. Arm Stepper Motor Printed Circuit Board

APPENDIX B - MECHANICAL DRAWINGS

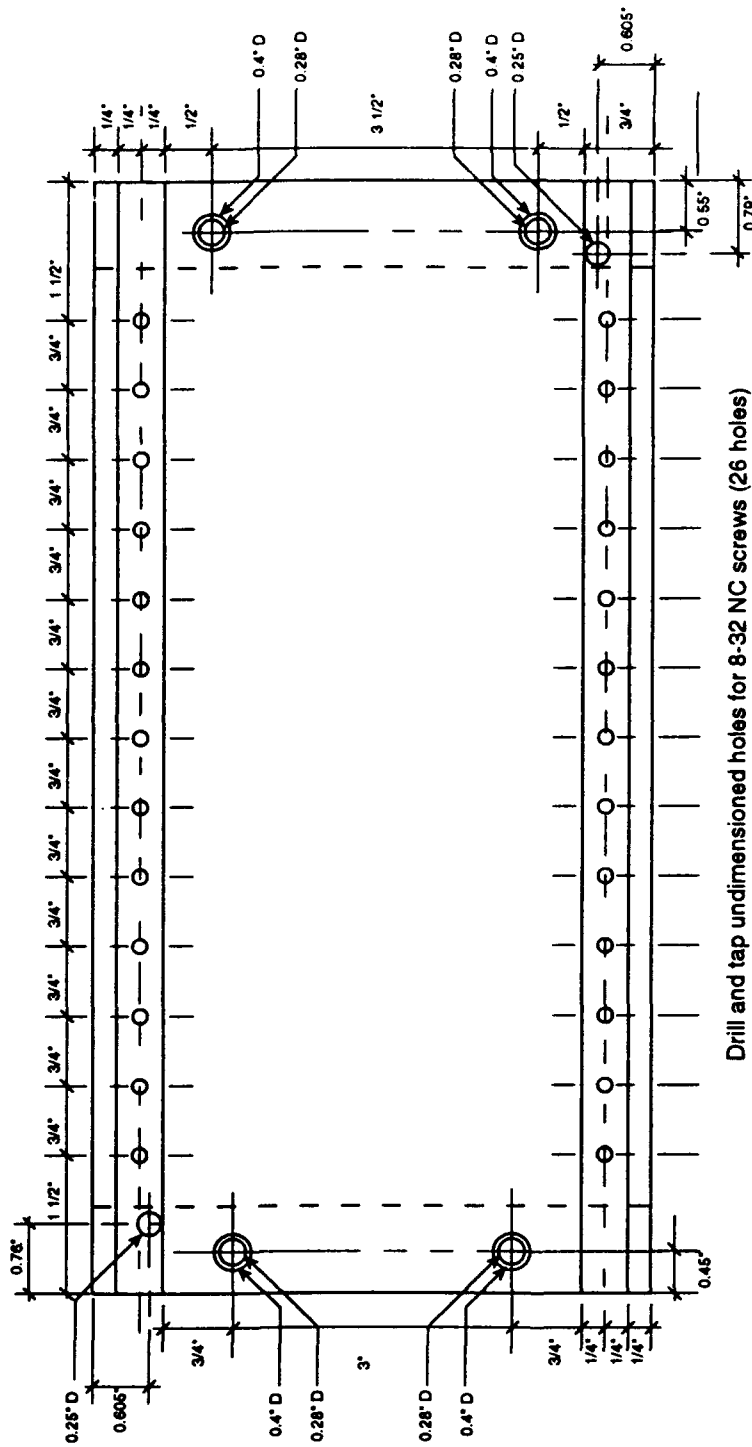


FIGURE 20 - Base Plate Top View

Wave Guide Stage Assembly	1 of 4
Wave Guide Base Plate	
Top View	
Tom Kensky WL/MLPO	Not to Scale
	27 Apr 92

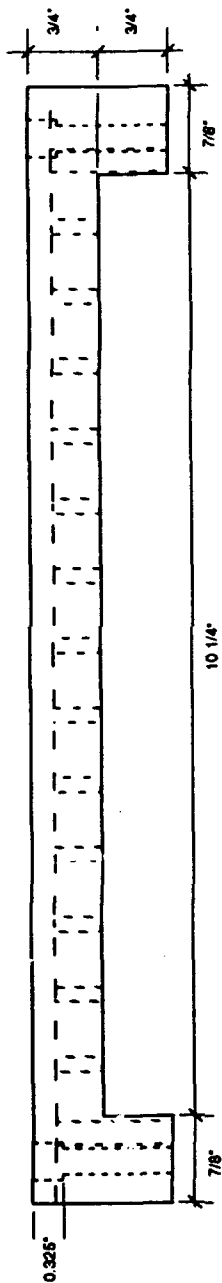
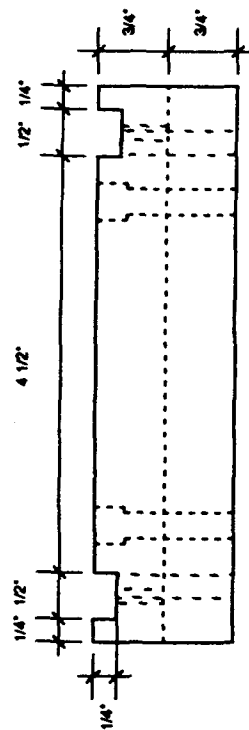


FIGURE 21 - Base Plate Side View

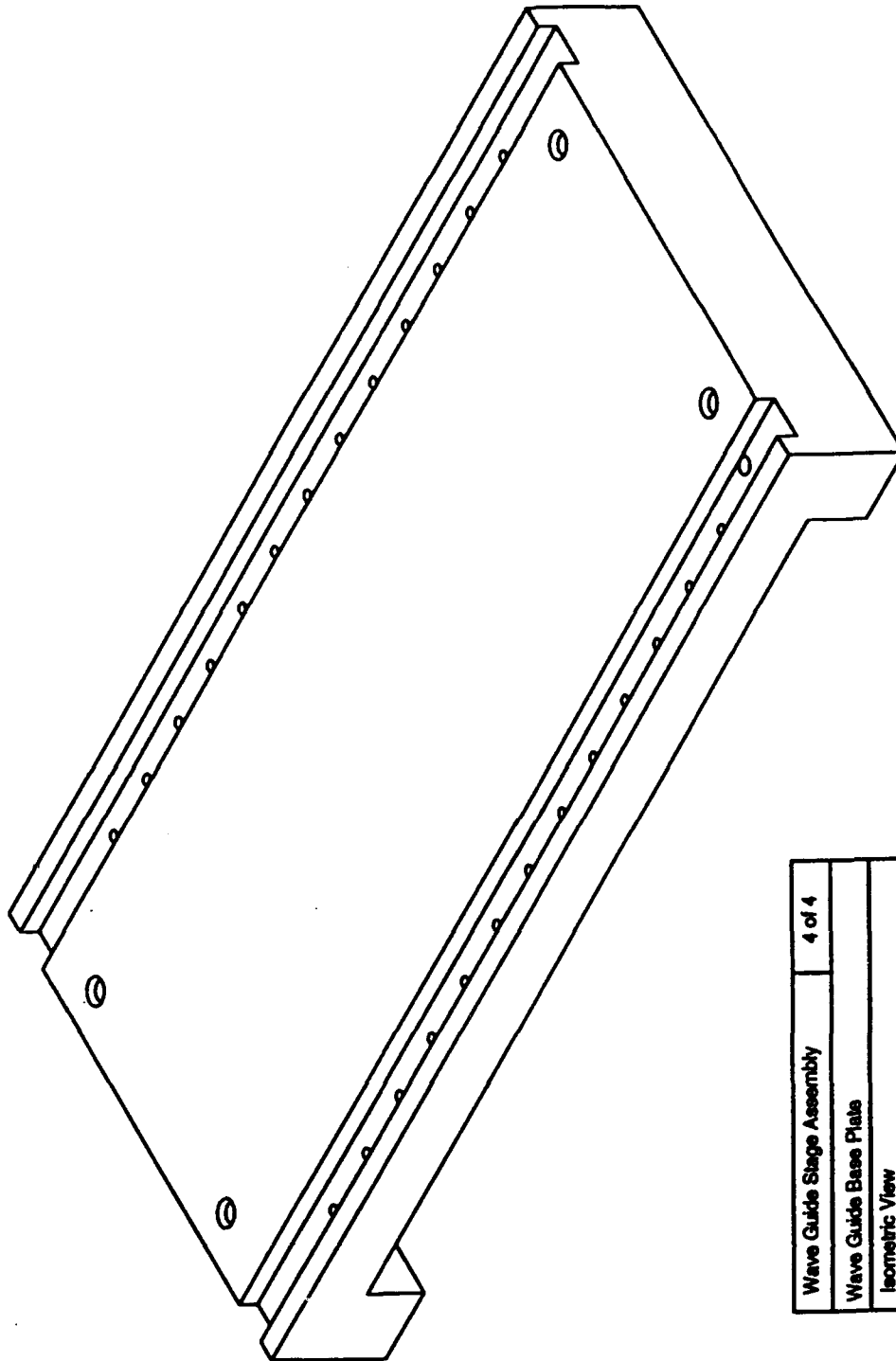
Wave Guide Stage Assembly	2 of 4
Wave Guide Base Plate	
Side View	
Tom Kensky WL/MLPO	Not to Scale
	27 Apr 92



Some hidden lines and surfaces are not shown for clarity.

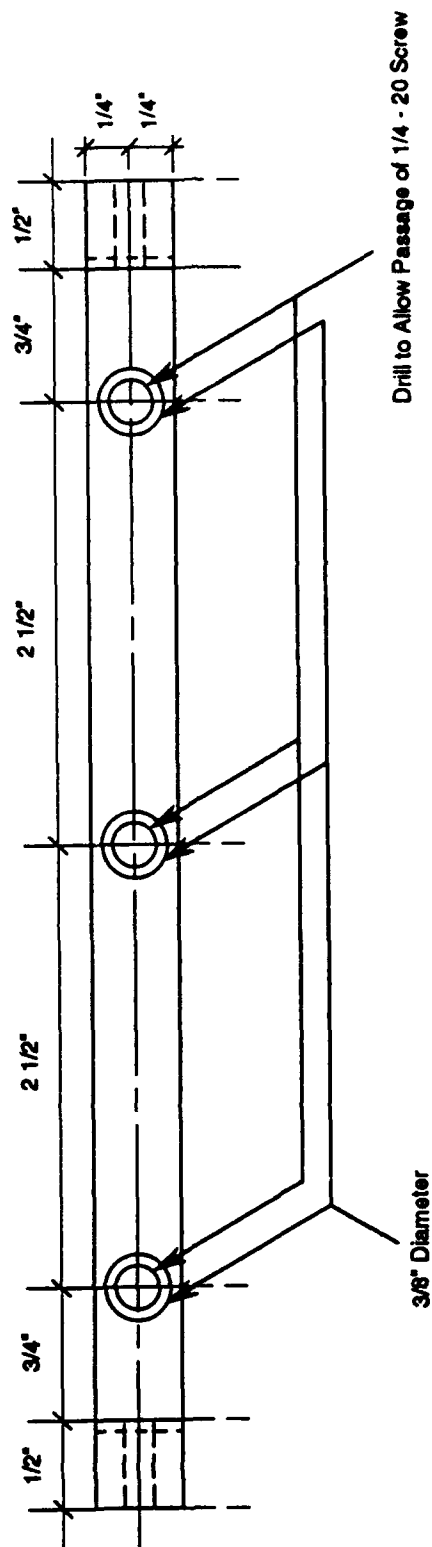
FIGURE 22 - Base Plate End View

Wave Guide Stage Assembly	3 of 4
Wave Guide Base Plate	
End View	
Tom Kensky WL/MLPO	Not to Scale
	27 Apr 92



Wave Guide Stage Assembly	4 of 4
Wave Guide Base Plate	
Isometric View	
Tom Keneky WL/MLPO	Not to Scale 27 Apr 82

FIGURE 23 - Base Plate Isometric View



Wave Guide Stage Assembly	1 of 4
Slide Bracket B Part I	
Top View	
Tom Kensky WL/MLPO	Not to Scale
	18 Jul 92

FIGURE 24 - Slide Bracket B I Top View

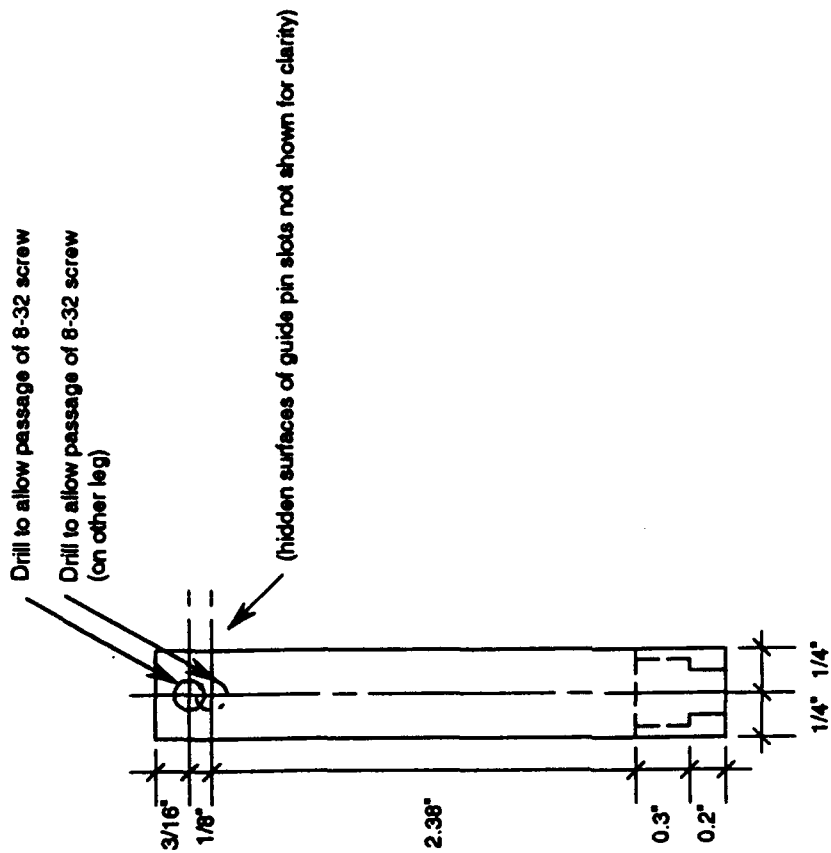


FIGURE 25 - Slide Bracket B I Side View

Wave Guide Stage Assembly	2 of 4
Slide Bracket B Part I	
Side View	
Tom Kensky WLM/PO	Not to Scale
	18 Jul 92

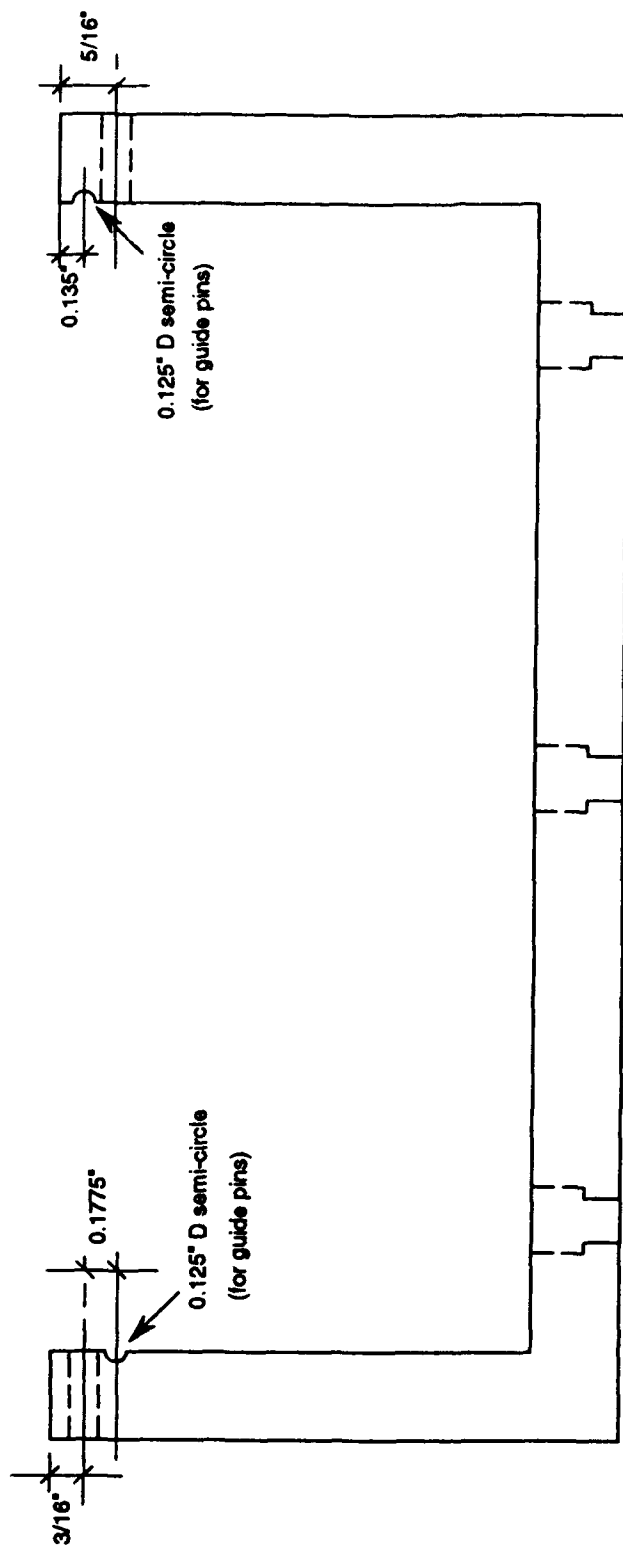


FIGURE 26 - Slide Bracket B I Front View

Wave Guide Stage Assembly	3 of 4
Slide Bracket B Part I	
Front View	
Tom Kensky WLMLPO	Not to Scale
18 Jul 92	

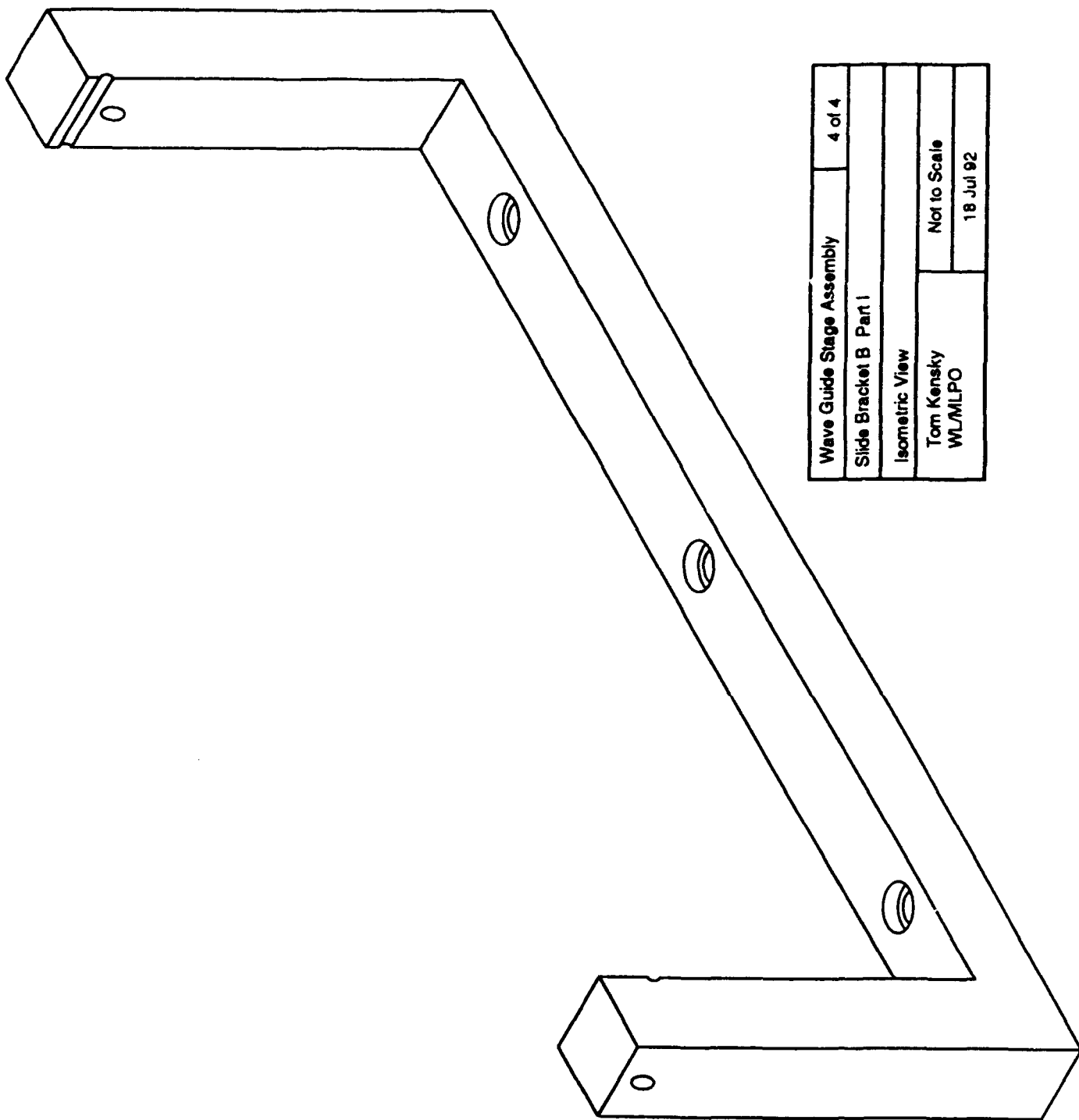
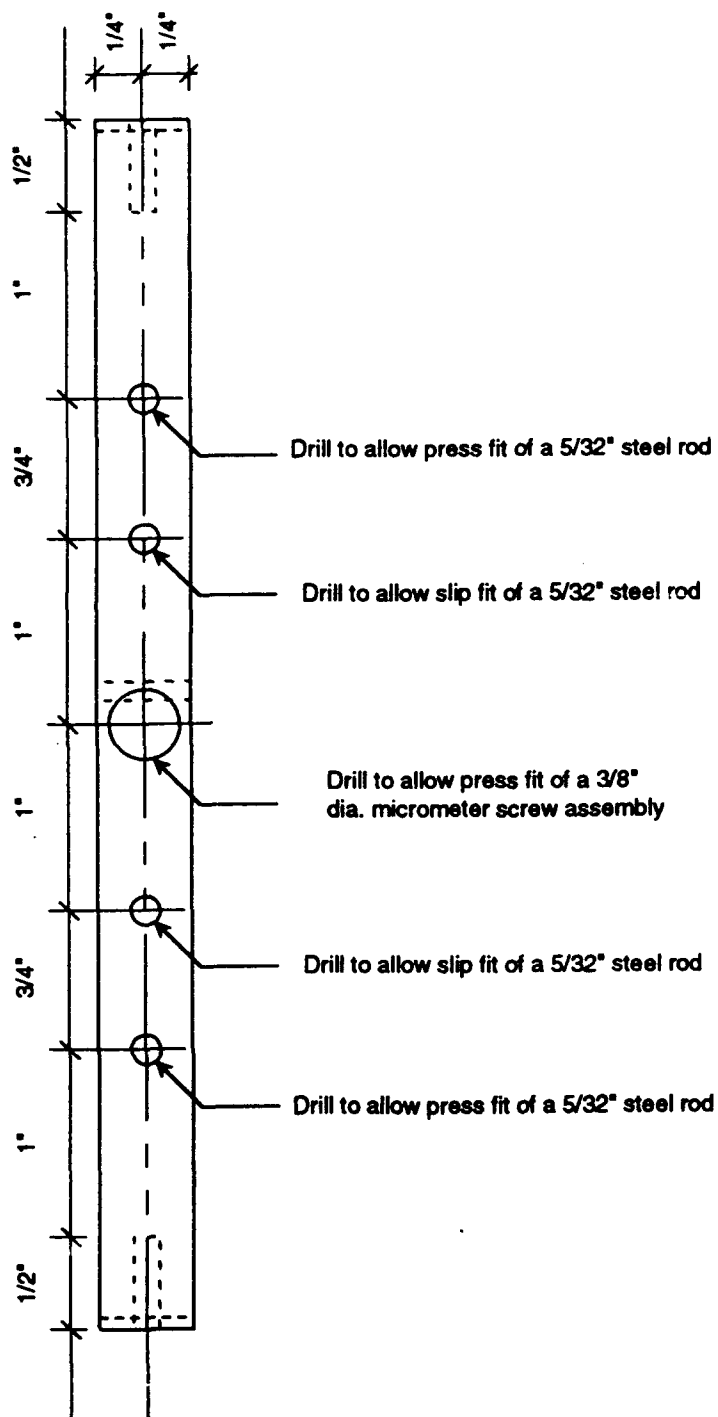


FIGURE 27 - Slide Bracket B I Isometric View



Wave Guide Stage Assembly	1 of 4
Slide Bracket B Part II	
Top View	
Tom Kensky WL/MLPO	Not to Scale
	18 Jul 92

FIGURE 28 - Slide Bracket B II Top View

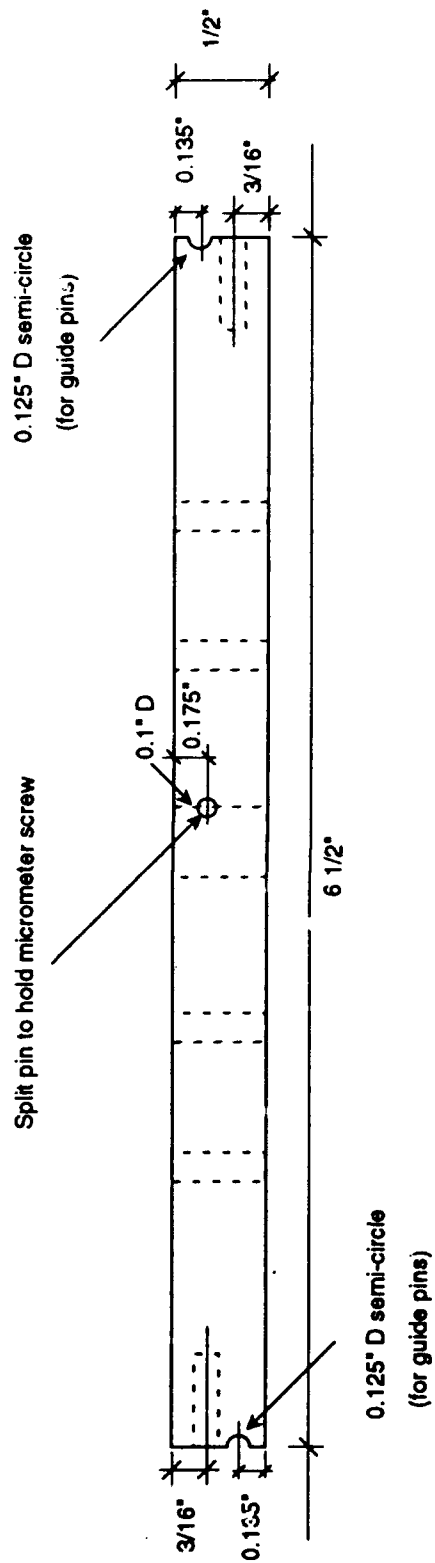


FIGURE 29 - Slide Bracket B II Front View

Wave Guide Stage Assembly	2 of 4
Slide Bracket B Part II	
Front View	
Tom Kensky WL/MLPO	Not to Scale
	18 Jul 92

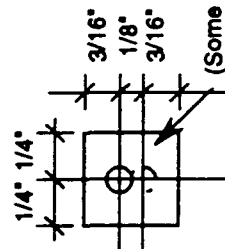
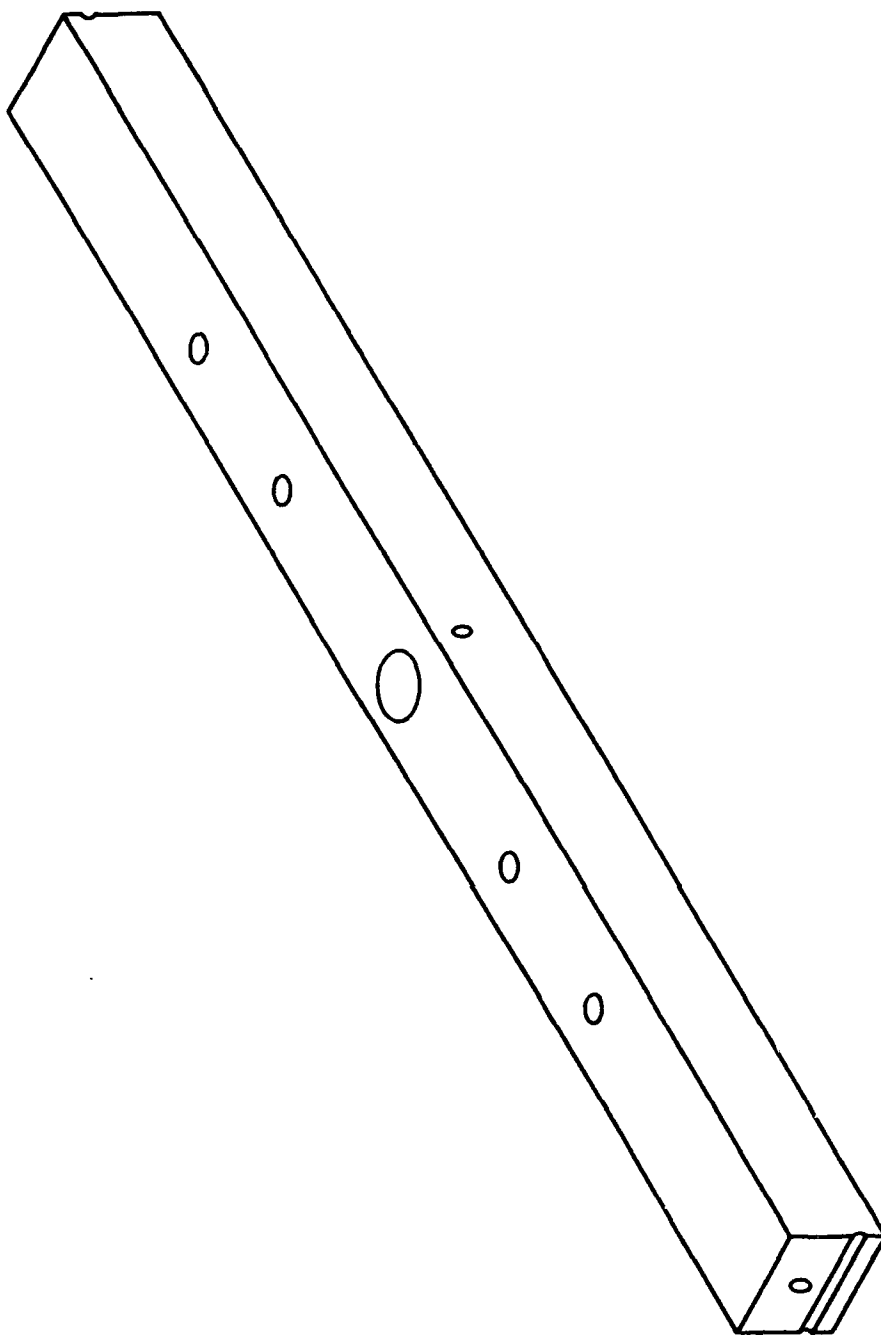


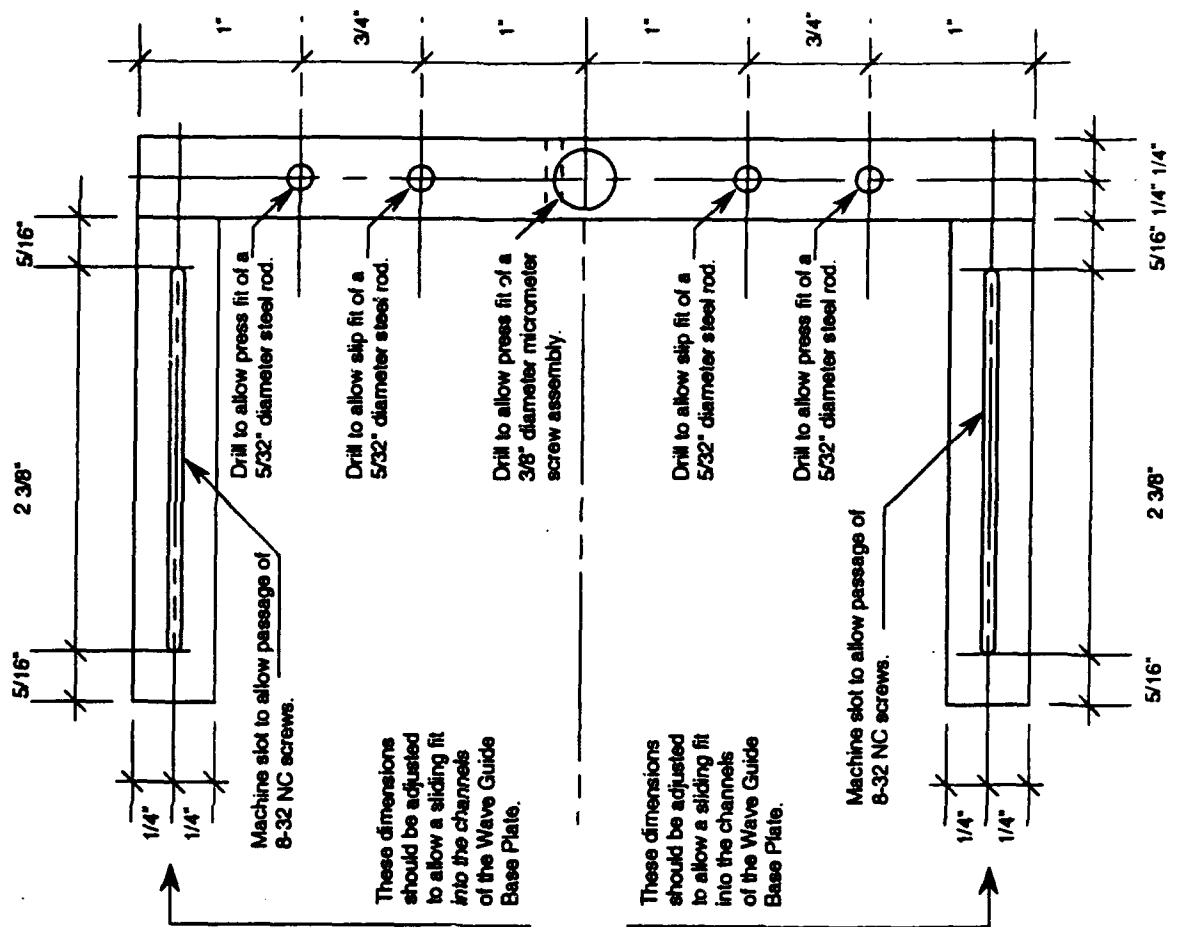
FIGURE 30 - Slide Bracket B II End View

Wave Guide Stage Assembly	3 of 4
Slide Bracket B Part II	
End View	
Tom Kensky WL/MLPO	Not to Scale
	18 Jul 92



Wave Guide Stage Assembly	4 of 4
Slide Bracket B Part II	
Isometric View	
Tom Kensky WL/MLPO	Not to Scale
18 Jul 92	

FIGURE 31 - Slide Bracket B II Isometric View



Wave Guide Stage Assembly	1 of 4
Slide Bracket A	
Top View	
Tom Kensky WL/MLPO	Not to Scale 21 Jul 92

FIGURE 32 - Slide Bracket A Top View

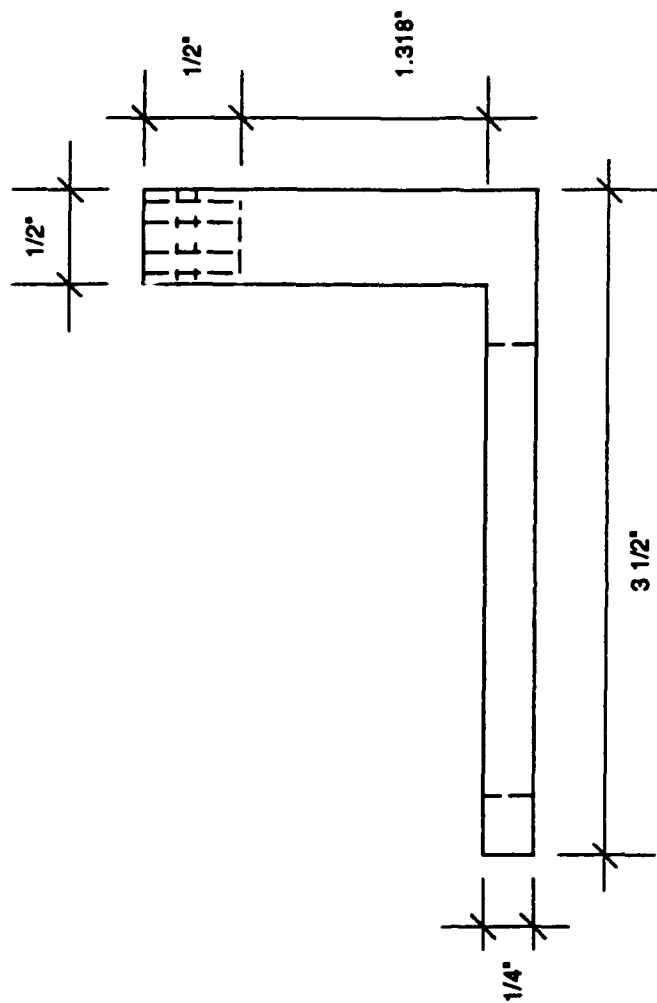


FIGURE 33 - Slide Bracket A Side View

Wave Guide Stage Assembly	2 of 4
Slide Bracket A	
Side View	
Tom Kensky WL/MLPO	Not to Scale
	21 Jul 92

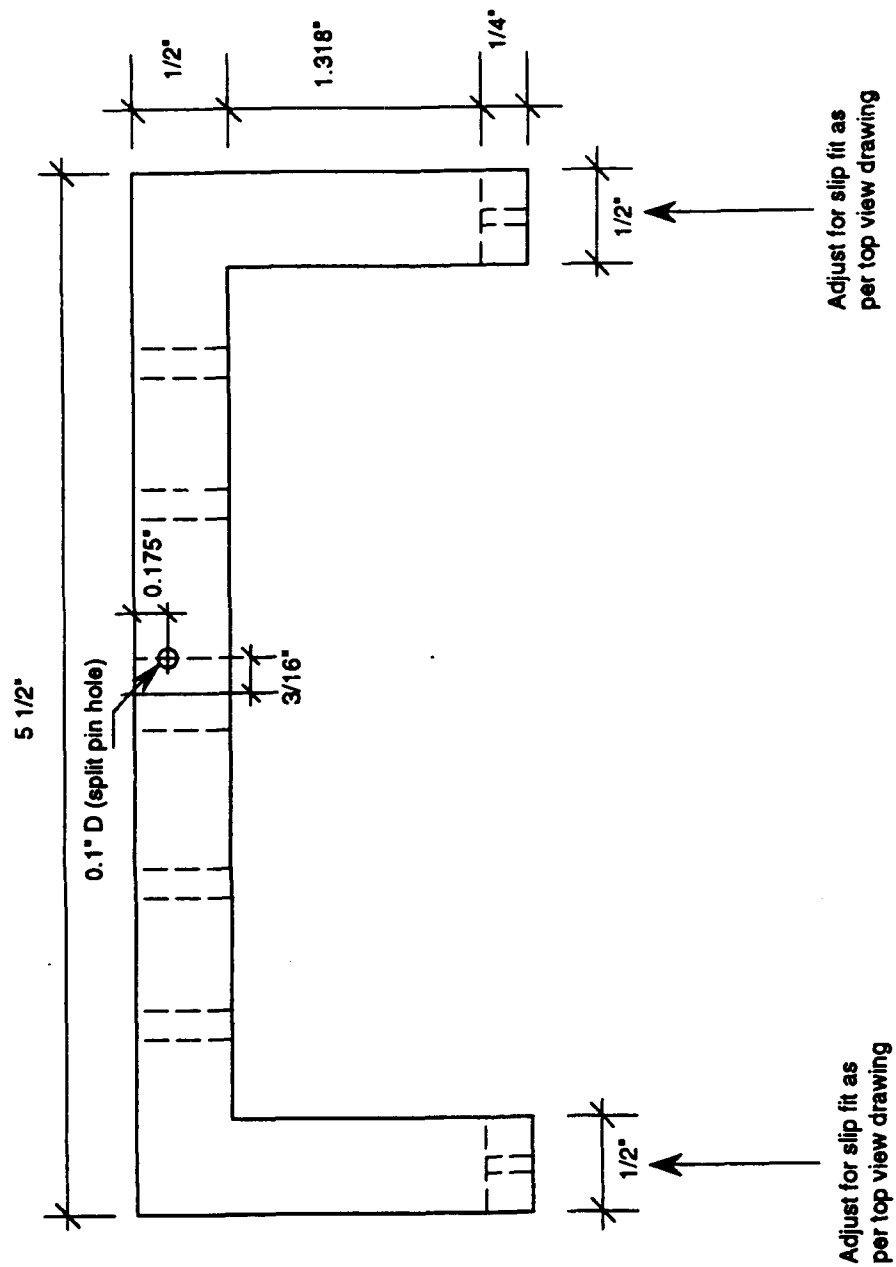
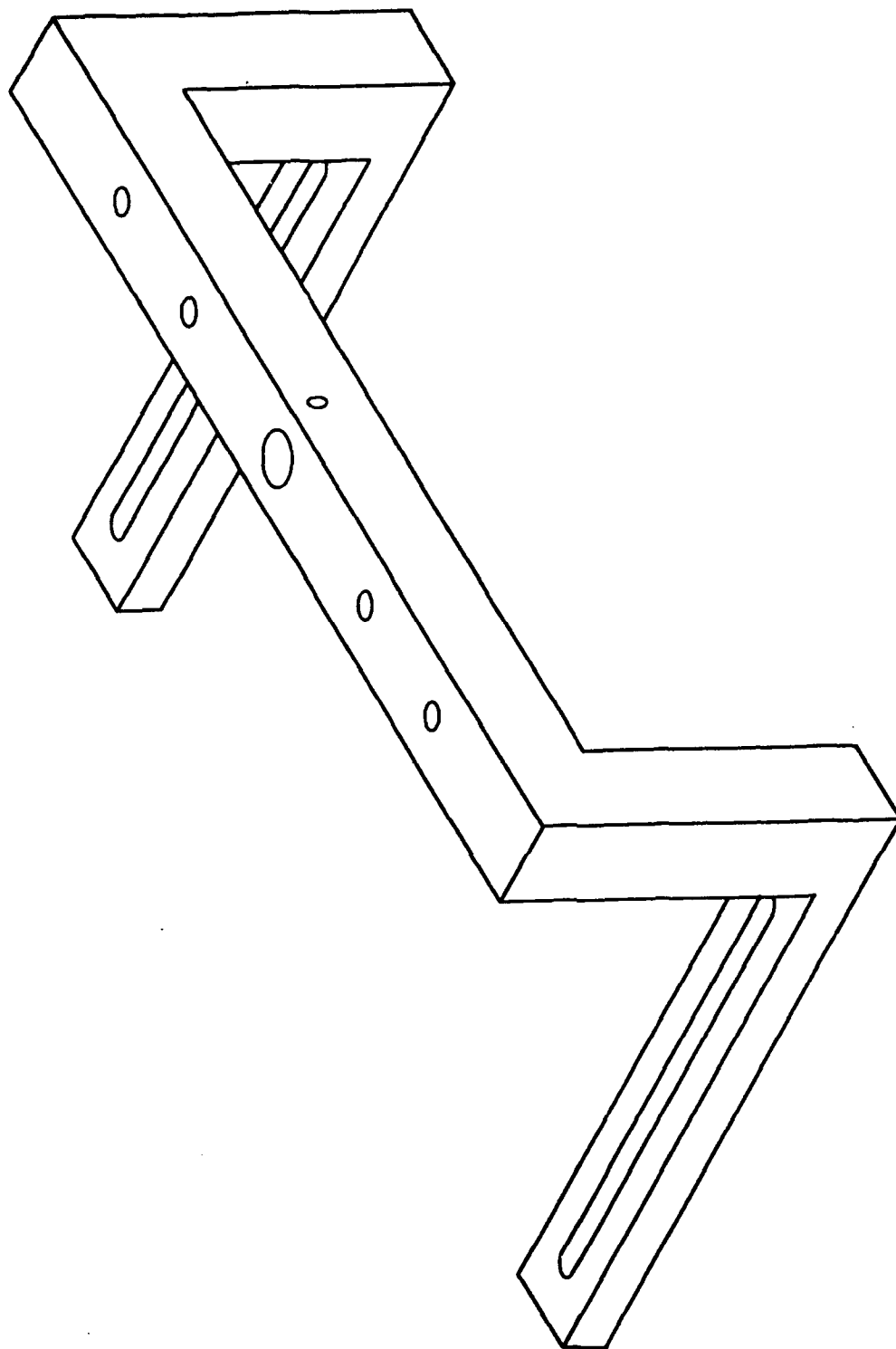


FIGURE 34 - Slide Bracket A Front View

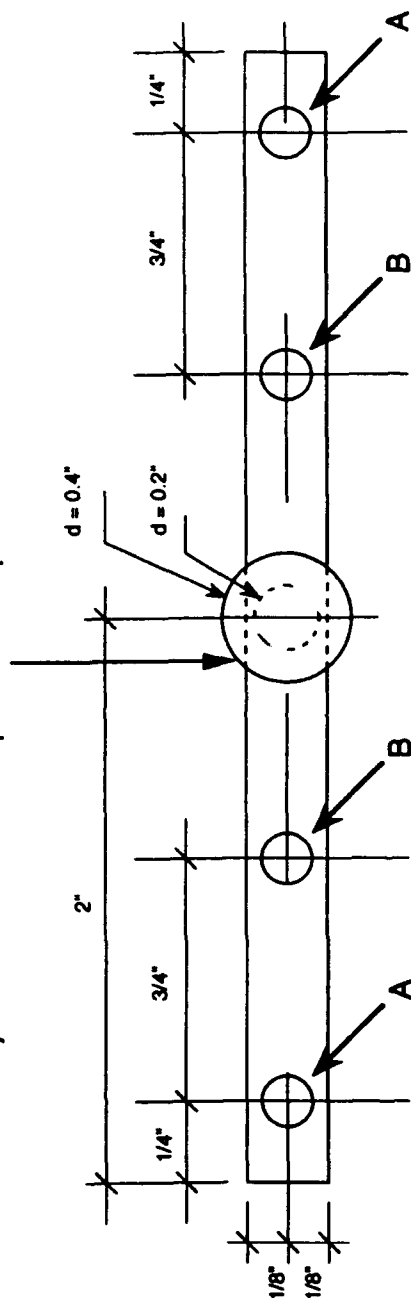
Wave Guide Stage Assembly	3 of 4
Slide Bracket A	
Front View	
Tom Kensky WL/MLPO	Not to Scale
	21 Jul 92



Wave Guide Stage Assembly	4 of 4
Slide Bracket A	
Isometric View	
Torn Kensky WL/MILPO	Not to Scale
	21 Jul 82

FIGURE 35 - Slide Bracket A Isometric View

Adjust dimension to allow slip fit into the cup of the Lower Guide Bracket



A. Drill to allow sliding passage (slip fit) of 5/32" diameter steel rod.

B. Drill to allow press fit of 5/32" diameter steel rod.

Wave Guide Stage Assembly	1 of 3
Upper Guide Bracket	
Top View	
Tom Kensky WU/MLPO	Not to Scale
	23 Jul 92

FIGURE 36 - Upper Guide Bracket Top View

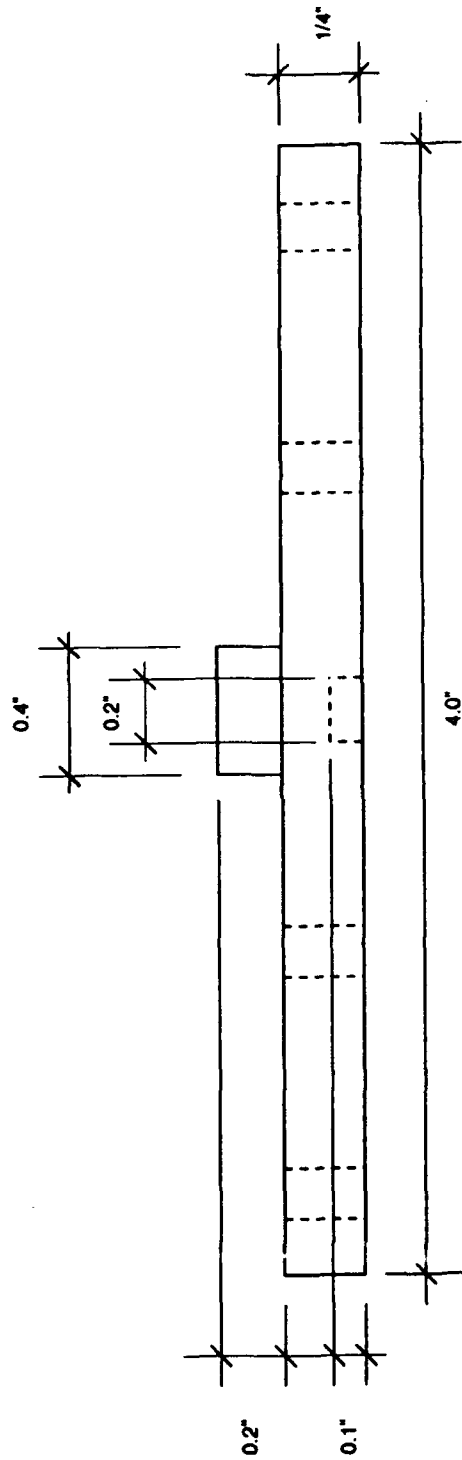
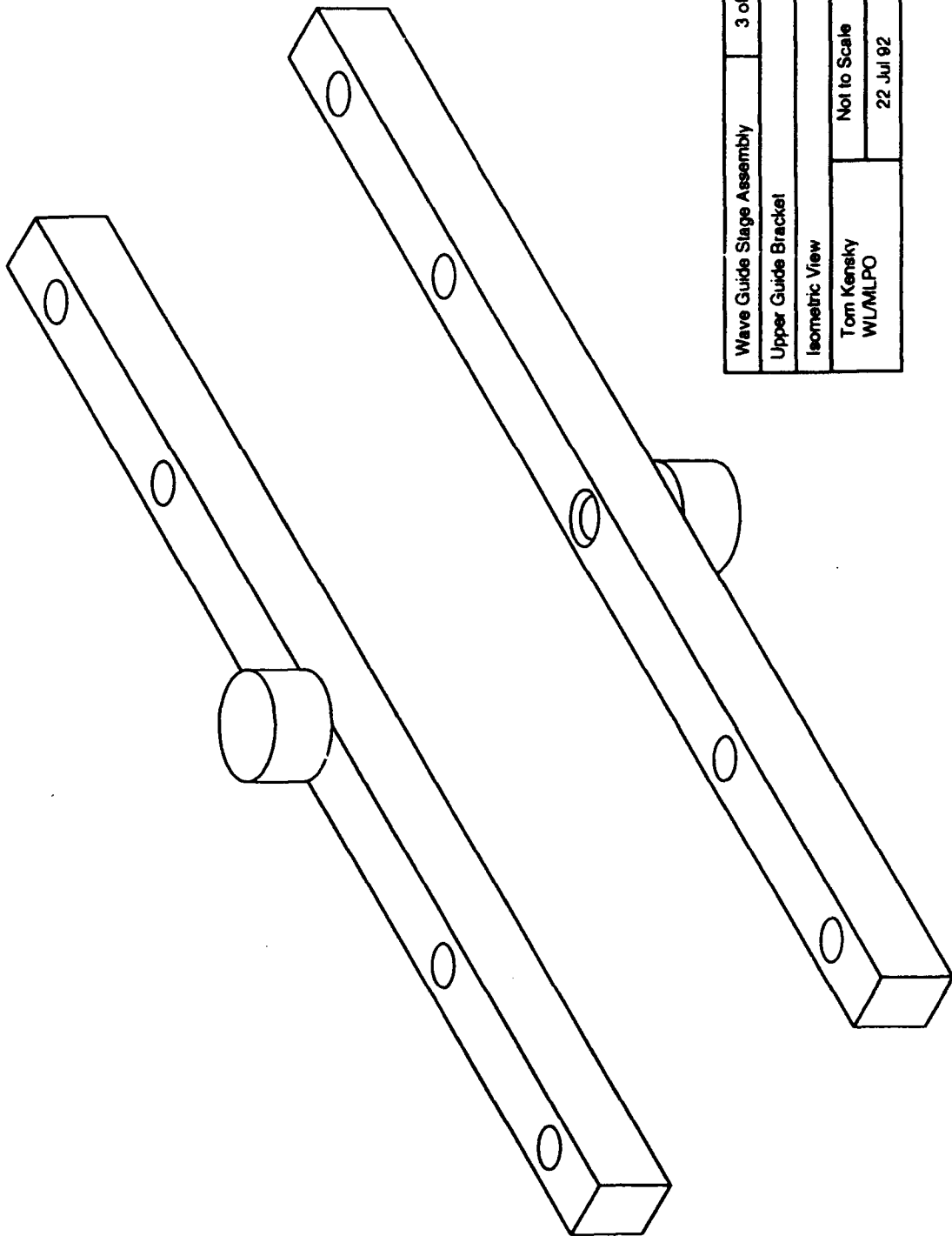


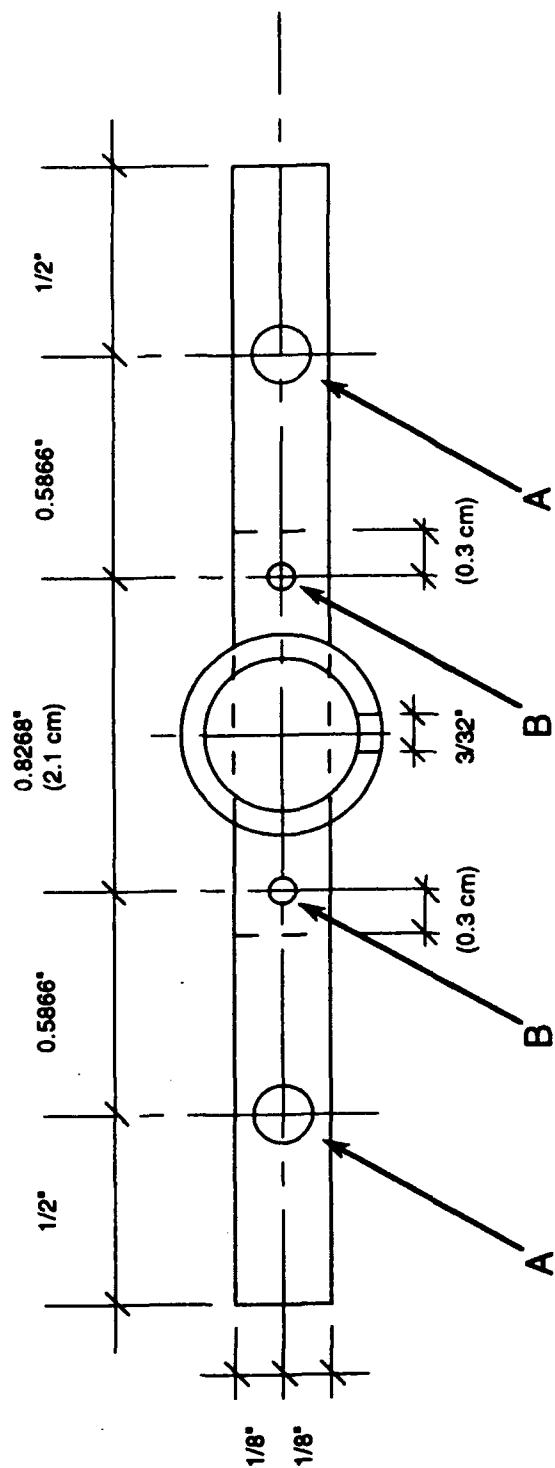
FIGURE 37 - Upper Bracket Front View

Wave Guide Stage Assembly	2 of 3
Upper Guide Bracket	
Front View	
Tom Kenaky WUMLPO	Not to Scale
	24 Jul 92



Wave Guide Stage Assembly	3 of 3
Upper Guide Bracket	
Isometric View	
Tom Keneky WU/MLPO	Not to Scale
22 Jul 92	

FIGURE 38 - Upper Guide Bracket Isometric View



A Drill to allow slip fit of a 5/32 diameter steel rod

B Drill and tap for 2-56 NC screw.

4 decimal place tolerances are for consistency in dimensioning only. Normal machining tolerances are allowable for actual fabrication.

Wave Guide Stage Assembly	1 of 3
Lower Guide Bracket	
Top View	
Tom Kenagy WL/MLPO	Not to Scale
	22 Jul 92

FIGURE 39 - Lower Guide Bracket Top View

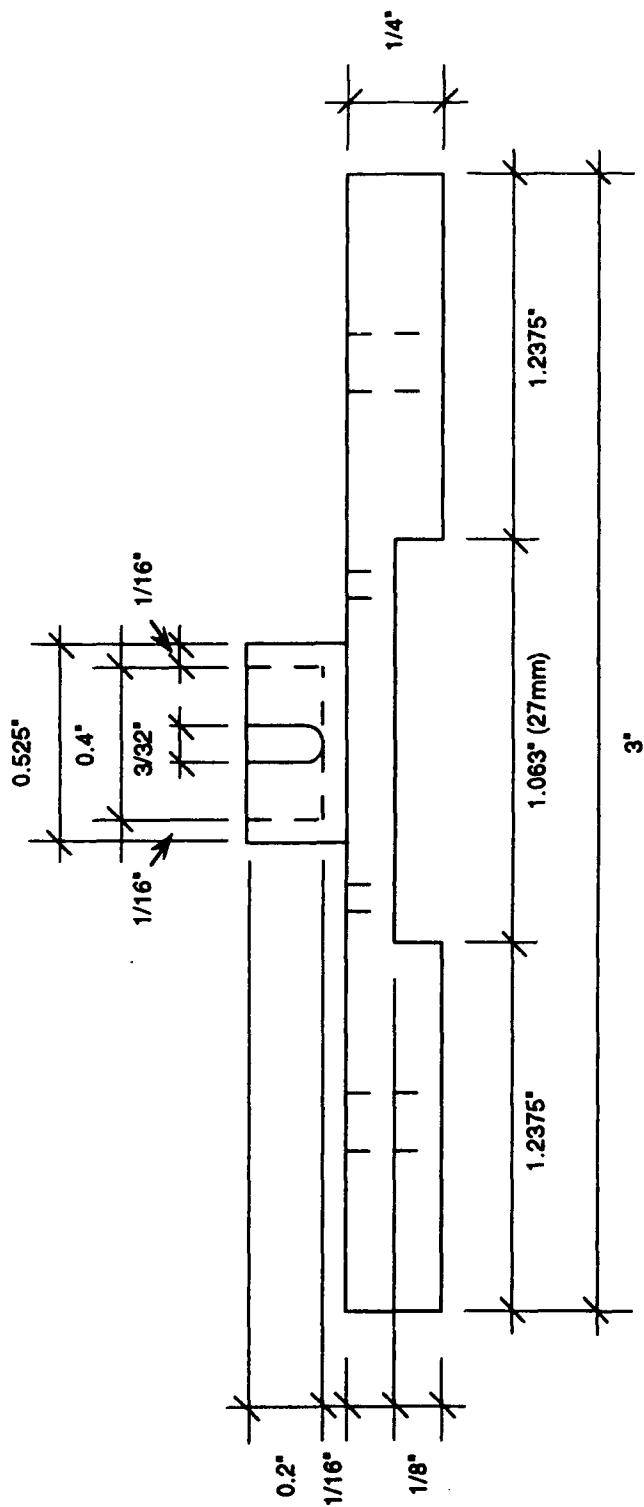
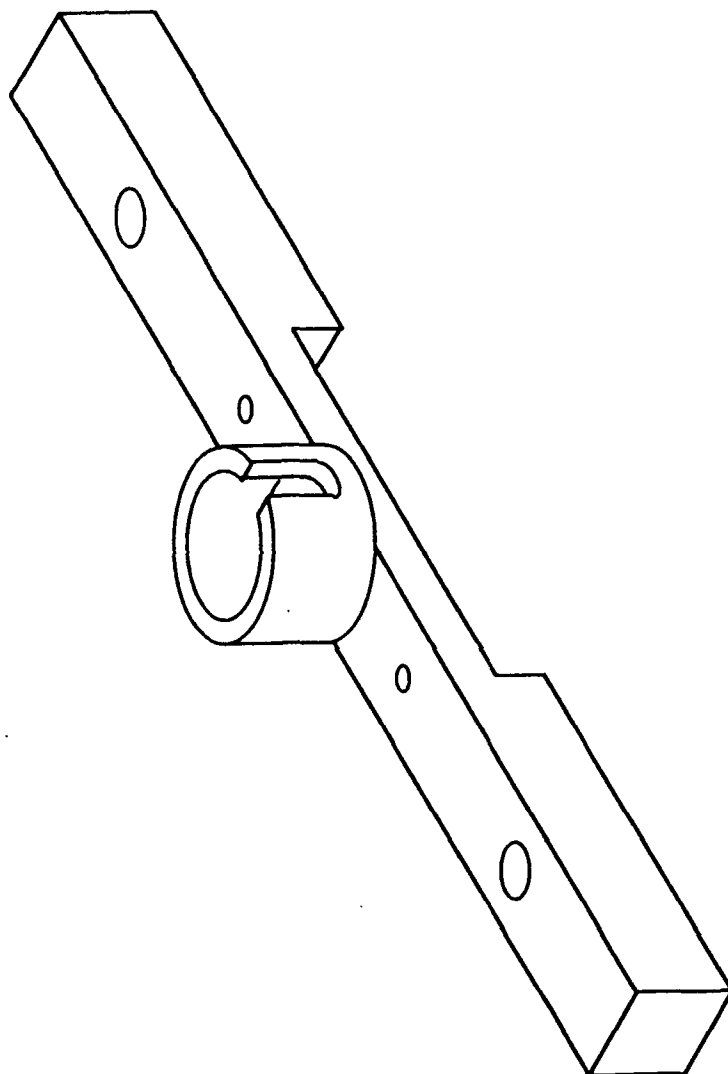


FIGURE 40 - Lower Guide Bracket Front View

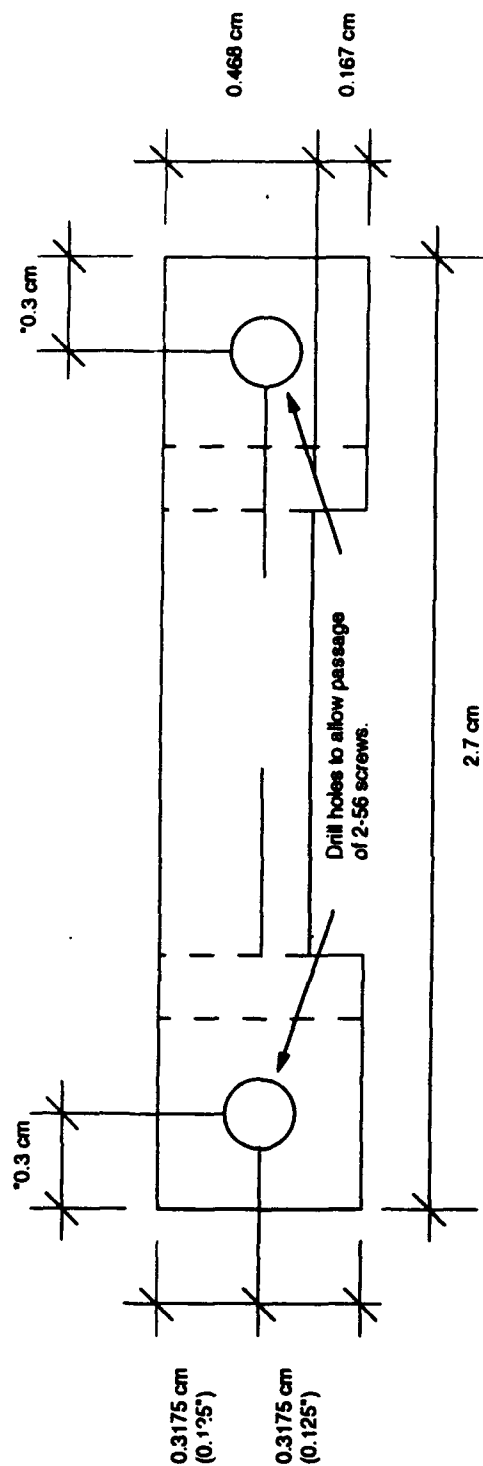
4 decimal place tolerances are for consistency in dimensioning only. Normal machining tolerances are allowable for actual fabrication.

Wave Guide Stage Assembly	2 of 3
Lower Guide Bracket	
Front View	
Tom Kensky WL/MLPO	Not to Scale
	22 Jul 92



Wave Guide Stage Assembly	3 of 3
Lower Guide Bracket	
Isometric View	
Tom Kensky WL/MLPO	Not to Scale
	22 Jul 92

FIGURE 41 - Lower Guide Bracket Isometric View



* Adjust these dimensions for slip fit into Lower Guide Bracket

Wave Guide Stage Assembly	1 of 4
Prism Holder A	
Top View	
Tom Kenesky WJ/MLPO	Not to Scale
	27 Jul 92

FIGURE 42 - Prism Holder A Top View

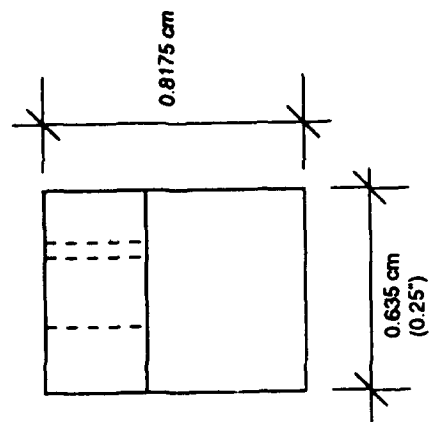


FIGURE 43 - Prism Holder A End View

Wave Guide Stage Assembly	2 of 4
Prism Holder A	
End View	
Tom Kenesky WU/MLPO	Not to Scale
	27 Jul 92

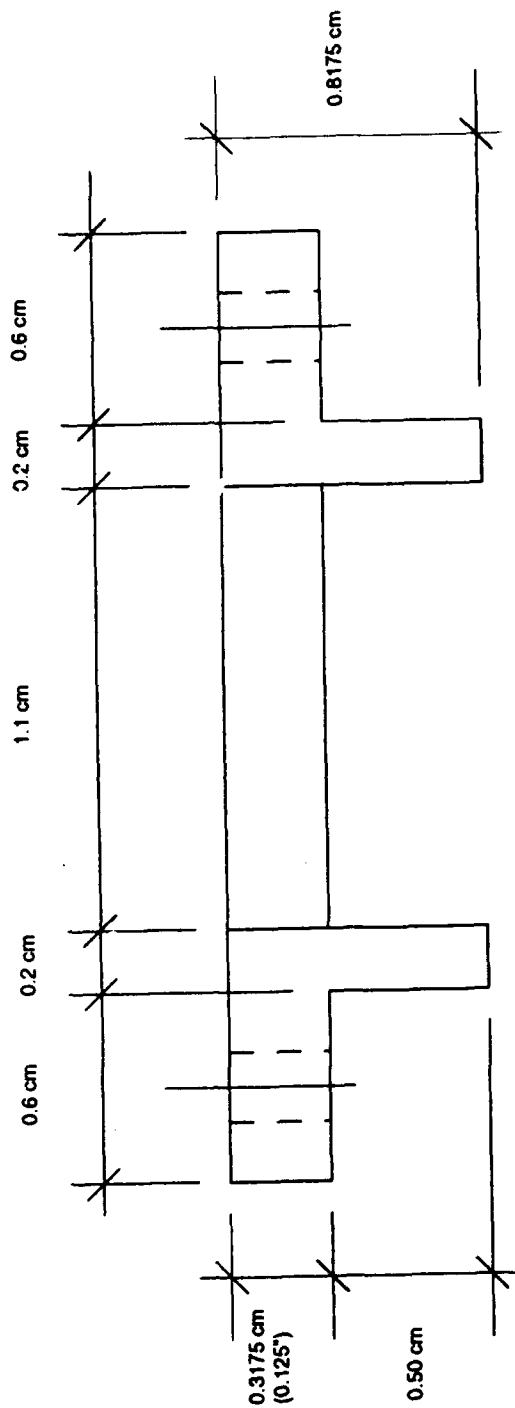
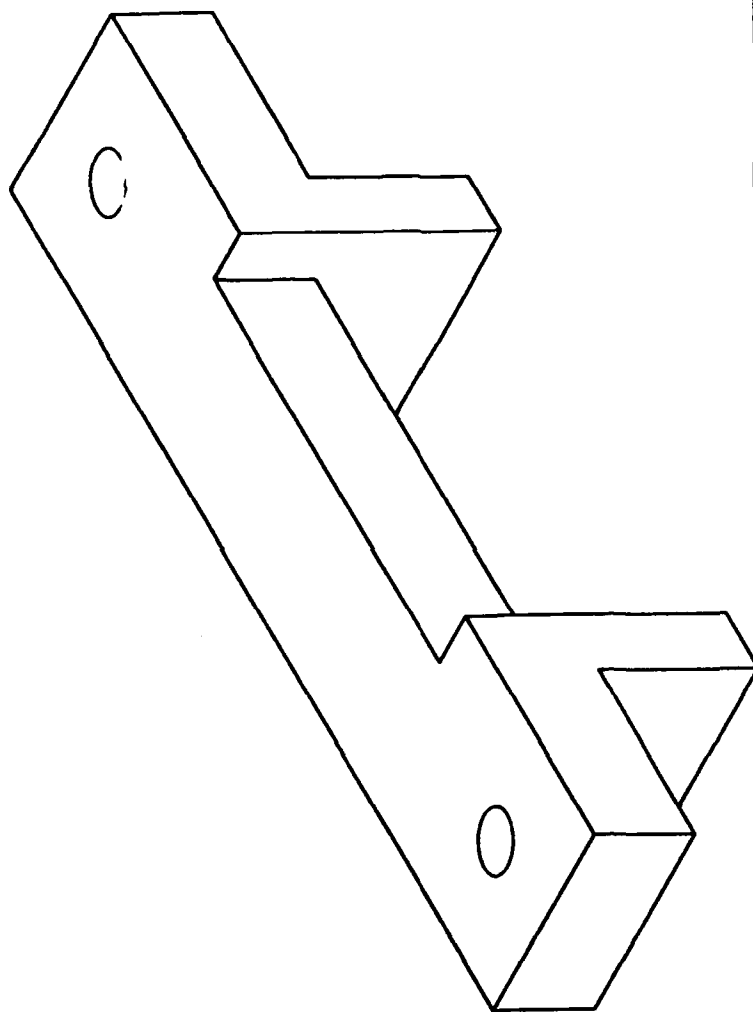


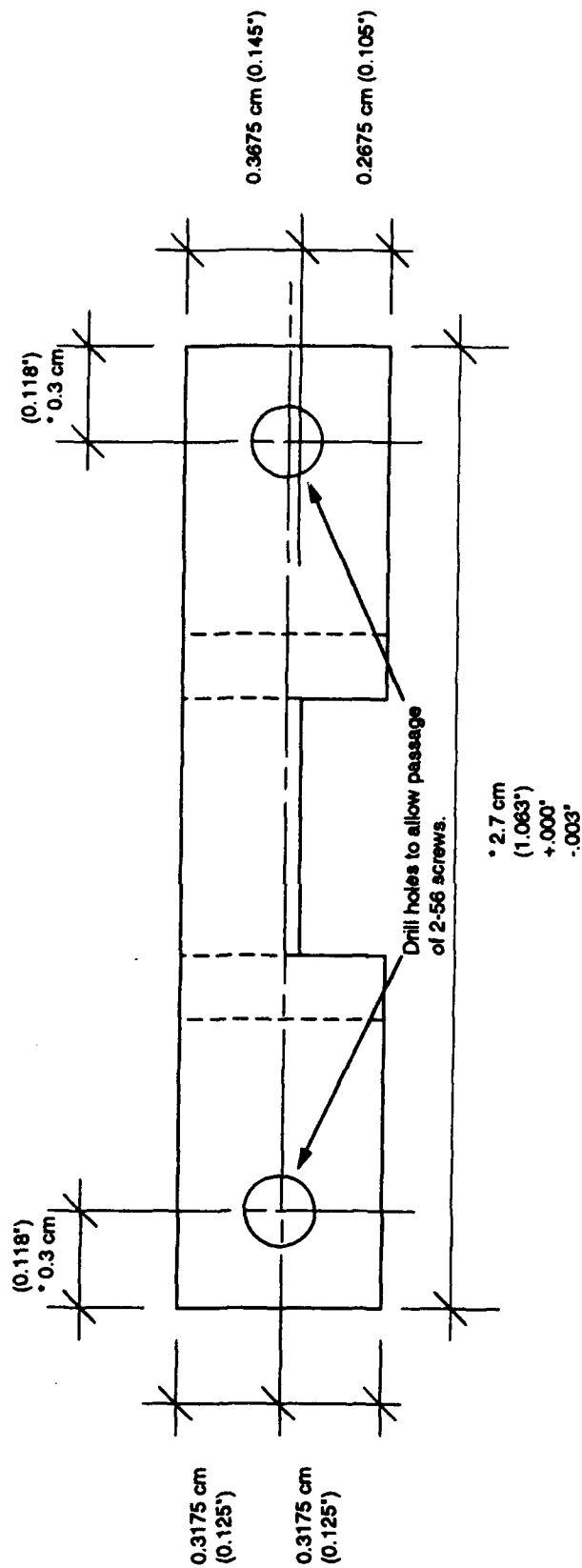
FIGURE 44 - Prism Holder A Front View

Wave Guide Stage Assembly	3 of 4
Prism Holder A	
Front View	
Tom Kensky WL/MLPO	Not to Scale
	28 Jul 92



Wave Guide Stage Assembly	4 of 4
Prism Holder A	
Isometric View	
Tom Kensky WL/MLPO	Not to Scale
	28 Jul 92

FIGURE 45 - Prism Holder A Isometric View



These lengths should be adjusted to allow slip fit into the lower guide bracket.

*

FIGURE 46 - Prism Holder B Top View

Wave Guide Stage Assembly	1 of 4
Prism Holder B	
Top View	
Tom Kensky WL/MLPO	Not to Scale
	24 Nov 92

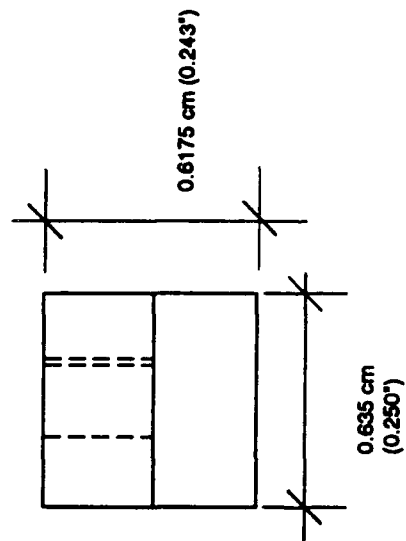
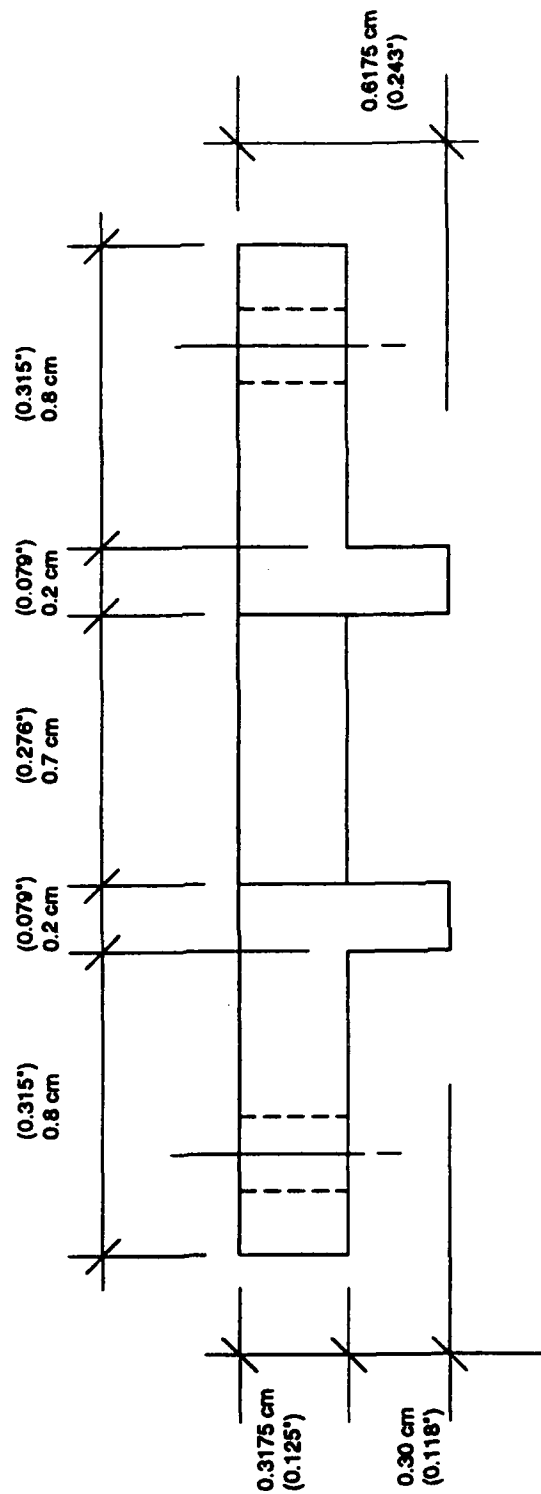


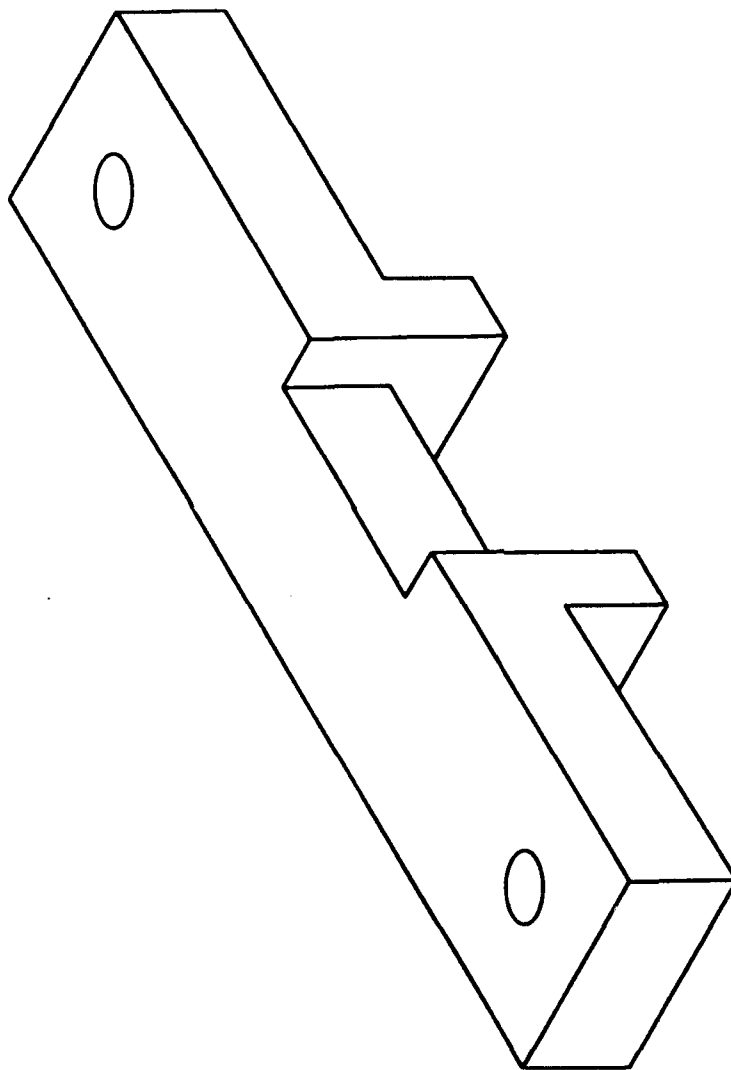
FIGURE 47 - Prism Holder B End View

Wave Guide Stage Assembly	2 of 4
Prism Holder B	
End View	
Tom Kenaky WL/MLPO	Not to Scale
	27 Jul 92



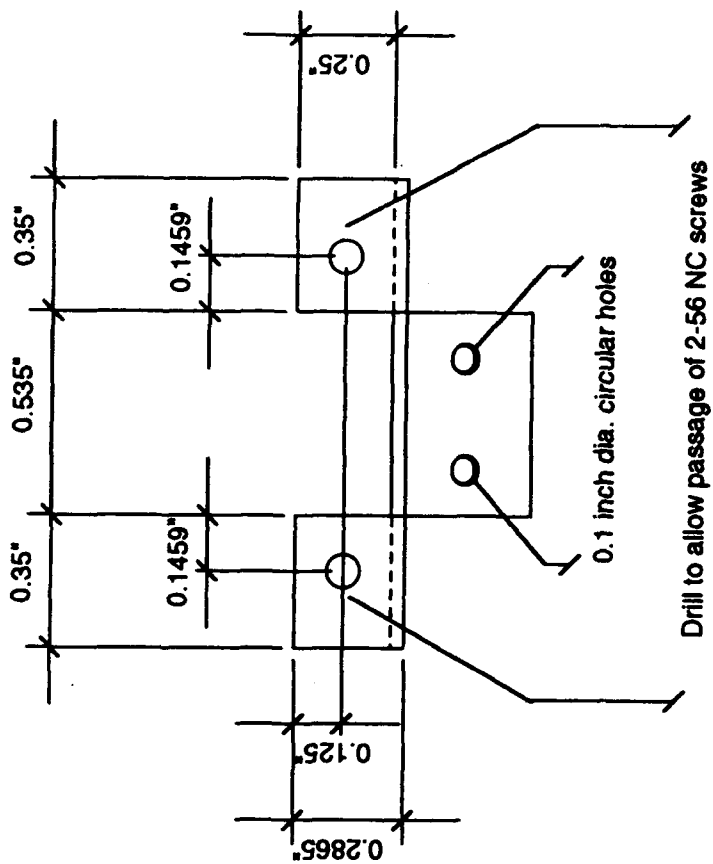
Wave Guide Stage Assembly	3 of 4
Prism Holder B	
Front View	
Tom Kenaky WL/MLPO	Not to Scale
	24 Nov 92

FIGURE 48 - Prism Holder B Front View



Wave Guide Stage Assembly	4 of 4
Prism Holder B	
Isometric View	
Tom Kensky WL/MLPO	Not to Scale
	24 Nov 92

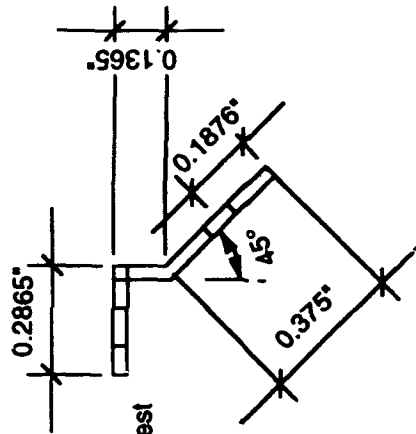
FIGURE 49 - Prism Holder B Isometric View



Aluminum thickness is 0.0365 inch or nearest

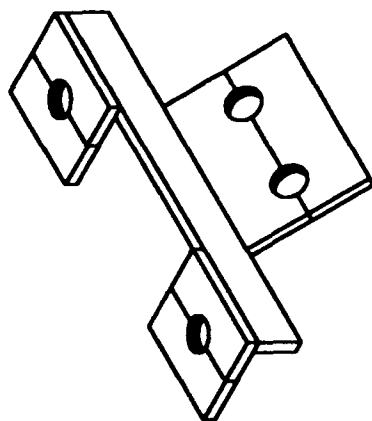
3 Prism Detector Holder	1 of 3
Top View	
Tom Kensky WL/MLPO Not to Scale	25 Jun 93

FIGURE 50 - Detector Holder A Top View



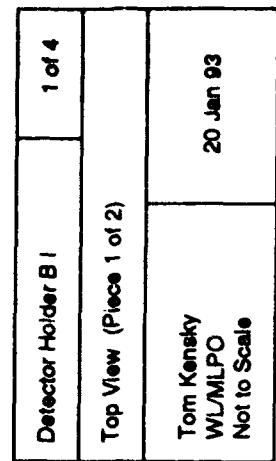
3 Prism Detector Holder	2 of 3
Side View	
Tom Kensky WL/MLPO Not to Scale	25 Jun 93

FIGURE 51 - Detector Holder A Side View

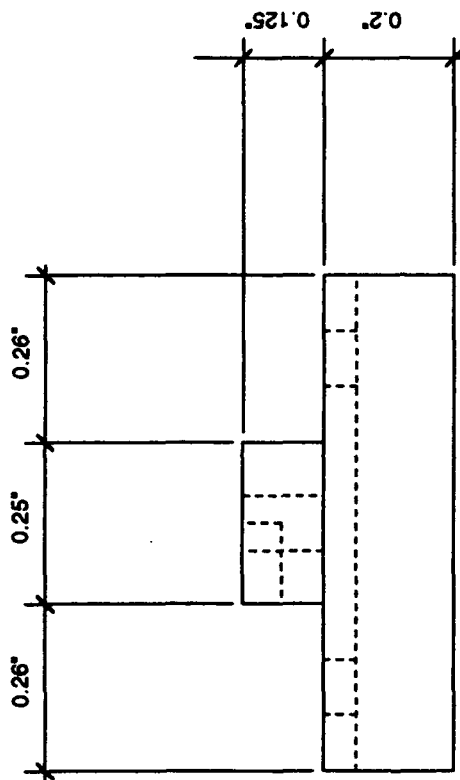


3 Prism Detector Holder	3 of 3
Isometric View	
Tom Kensky WL/MLPO Not to Scale	25 Jun 93

FIGURE 52 - Detector Holder A Isometric View

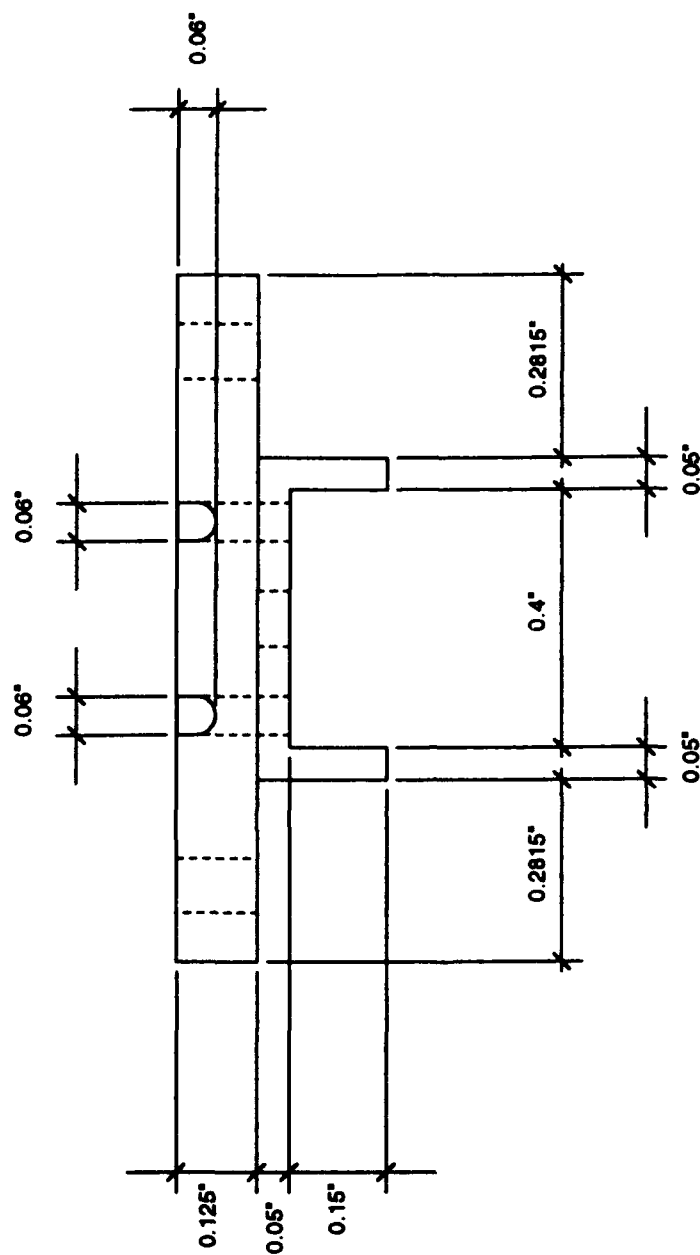


70



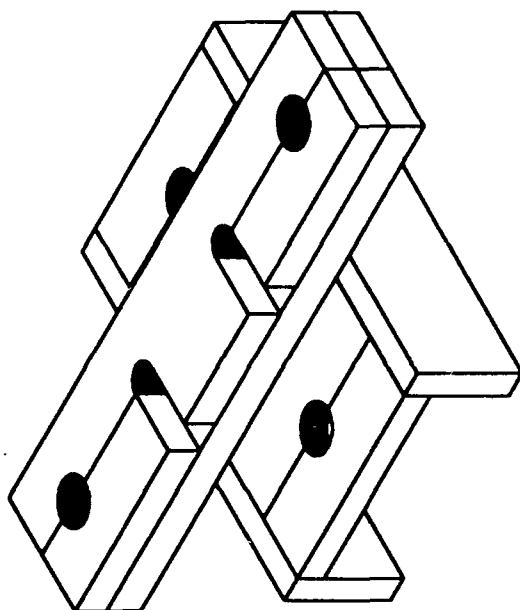
Detector Holder B I	2 of 4
End View (Piece 1 of 2)	
Tom Kensky WL/MLPO Not to Scale	20 Jan 93

FIGURE 54 - Detector Holder B I End View



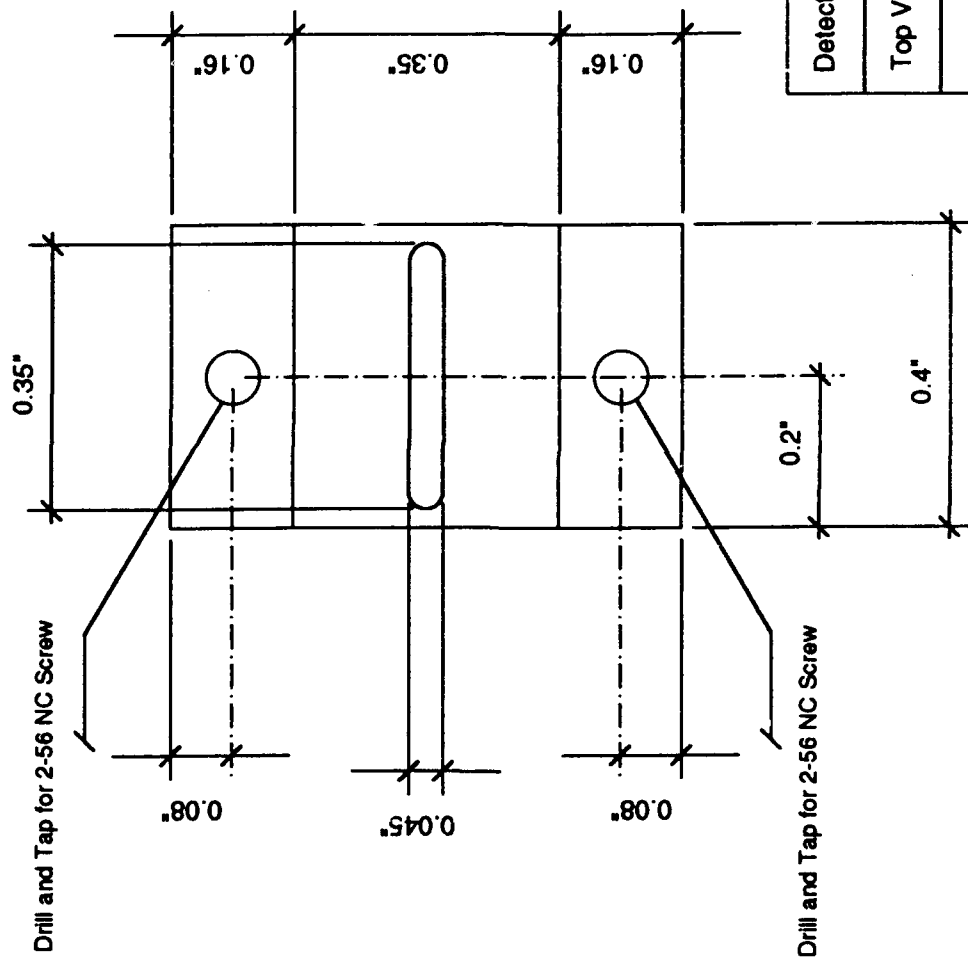
Detector Holder B I	3 of 4
Front View (Piece 1 of 2)	
Tom Kensky WL/MLPO Not to Scale	20 Jan 93

FIGURE 55 - Detector Holder B I Front View



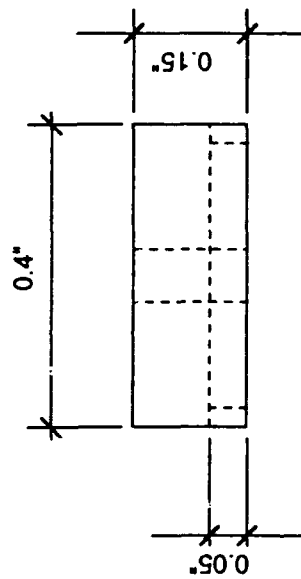
Detector Holder B I	4 of 4
Isometric View (Piece 1 of 2)	
Tom Kensky WL/MLPO Not to Scale	20 Jan 93

FIGURE 56 - Detector Holder B I Isometric View



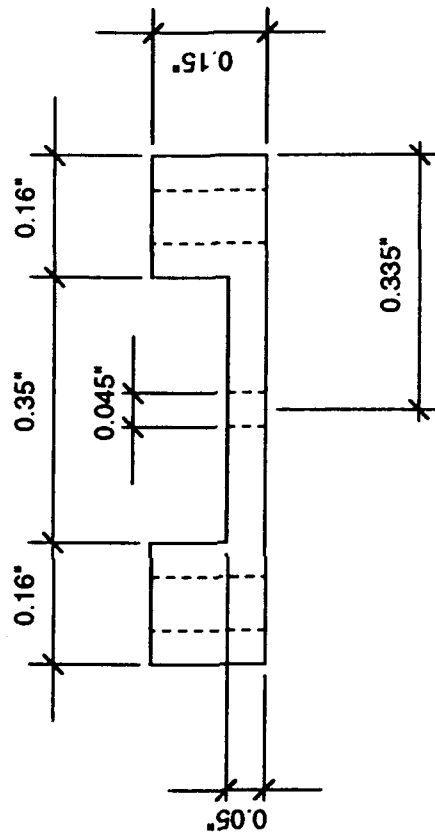
Detector Holder B II	1 of 4
Top View (Piece 2 of 2)	
Tom Kensky WL/MLPO Not to Scale	20 Jan 93

FIGURE 57 - Detector Holder B II Top View



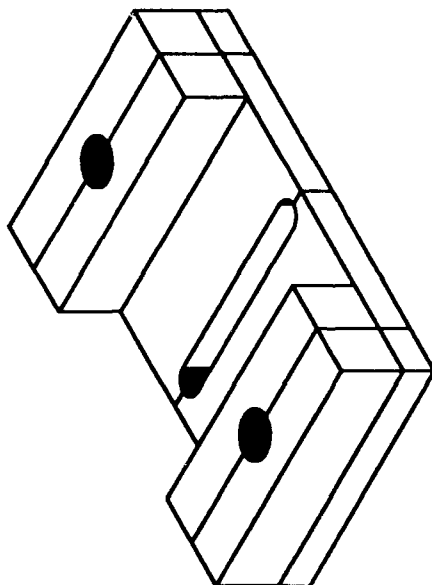
Detector Holder B II	2 of 4
End View (Piece 2 of 2)	
Tom Kensky WL/MLPO Not to Scale	20 Jan 93

FIGURE 58 - Detector Holder B II End View



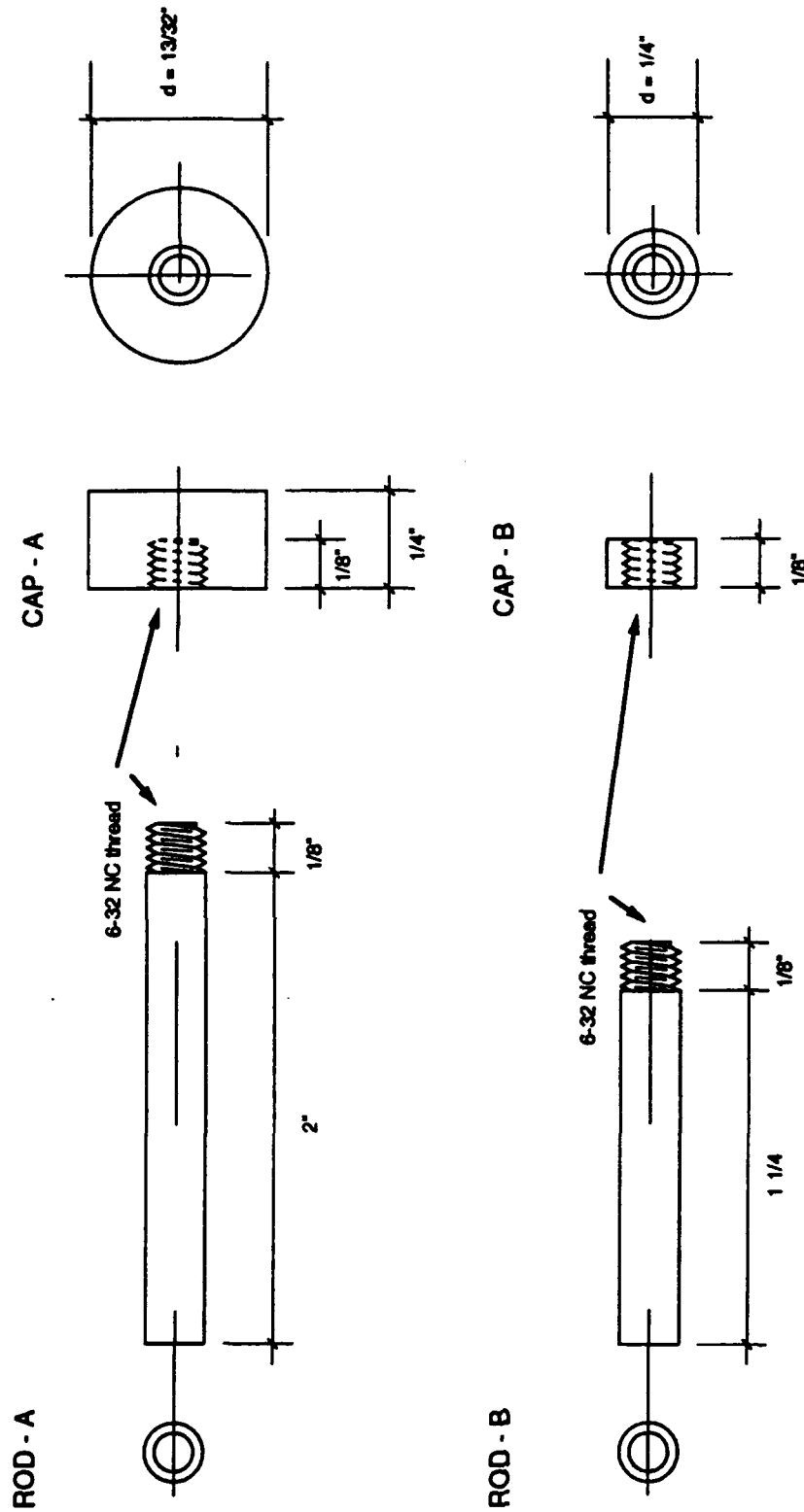
Detector Holder B II	3 of 4
Front View (Piece 2 of 2)	
Tom Kensky WL/MLPO Not to Scale	20 Jan 93

FIGURE 59 - Detector Holder B II Front View



Detector Holder B IIr	4 of 4
Perspective View (Piece 2 of 2)	
Tom Kensky WL/MLPO Not to Scale	20 Jan 93

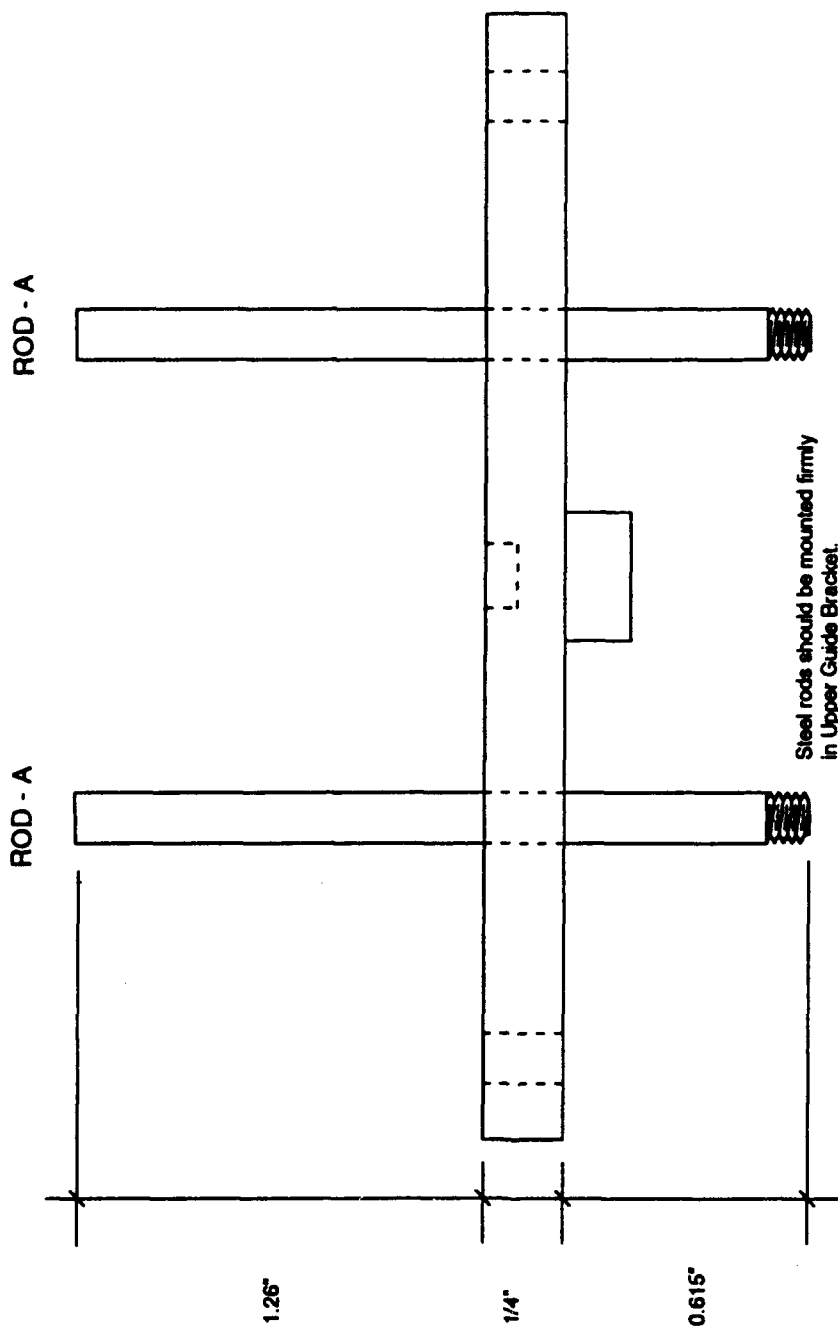
FIGURE 60 - Detector Holder B II Isometric View



Rods are 5/32 diameter steel (oxide black)
Caps are black anodized aluminum

Wave Guide Stage Assembly	1 of 4
Rods A and B	Caps A and B
Tom Kenesky WU/MILPO	Not to Scale
	28 Jul 92

FIGURE 61 - Rods and Caps



Wave Guide Stage Assembly	2 of 4
Rod mounting position in Upper Guide Bracket	
Front View	
Tom Kenaky WL/MLPO	Not to Scale
	28 Jul 92

FIGURE 62 - Upper Guide Bracket Assembly

Steel rods should be mounted firmly in Slide Bracket A. End of bar should be flush with top surface of Bracket.

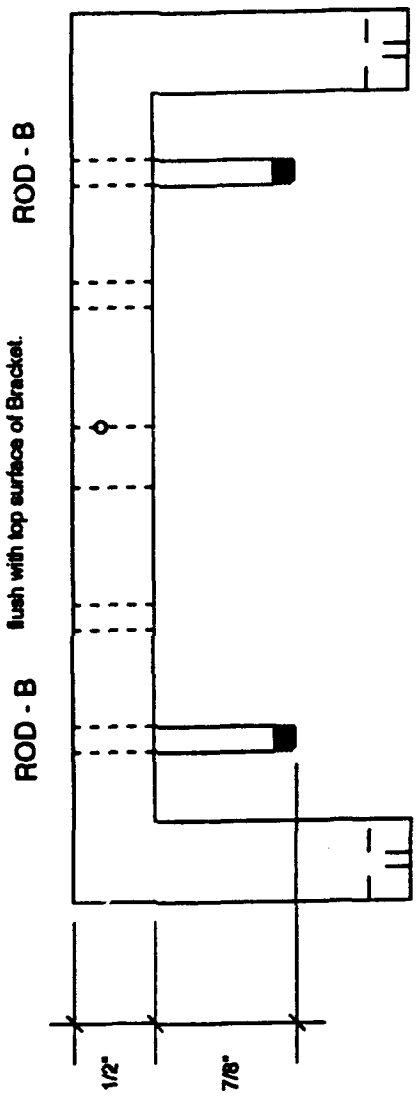
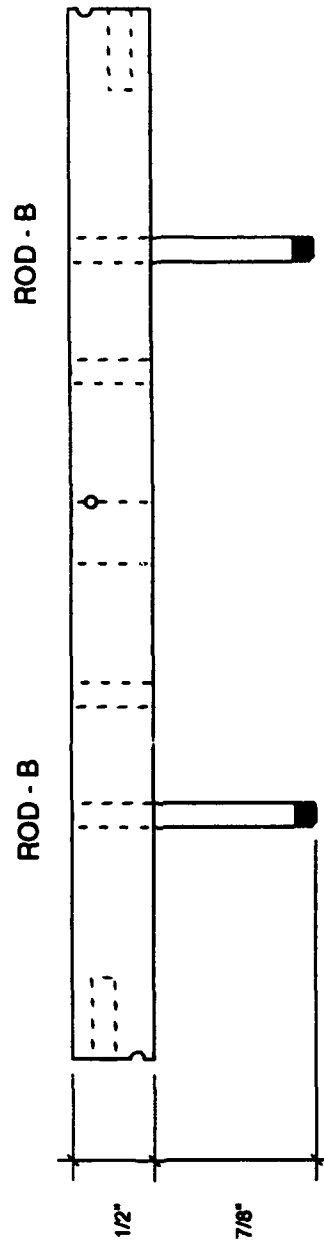


FIGURE 63 - Slide Bracket Assembly

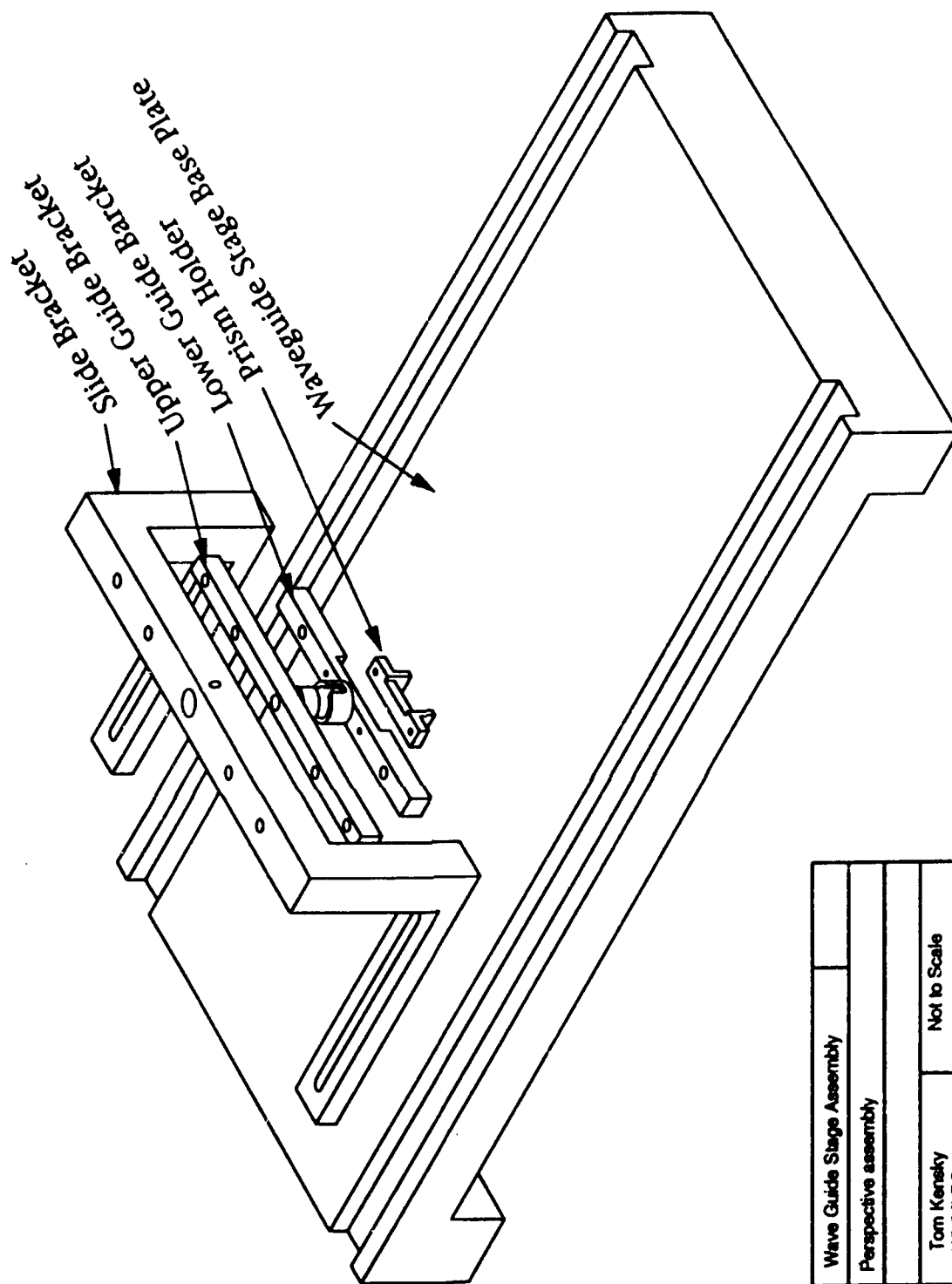
Wave Guide Stage Assembly	3 of 4
Rod mounting position in Slide Bracket A	
Front View	
Tom Keneky WUMILPO	Not to Scale
	29 Jul 92

Steel rods should be mounted firmly in Slide Bracket B. End of bar should be flush with top surface of Bracket.



Wave Guide Stage Assembly	4 of 4
Rod mounting position in Slide Bracket B	
Front View	
Tom Kenesky WLM/LPO	Not to Scale
	29 Jul 92

FIGURE 64 - Slide Bracket B Assembly



Wave Guide Stage Assembly	
Perspective assembly	
Tom Kensky WL/MLPO	Not to Scale
28 Jul 92	

FIGURE 65 - Stage Assembly Exploded View

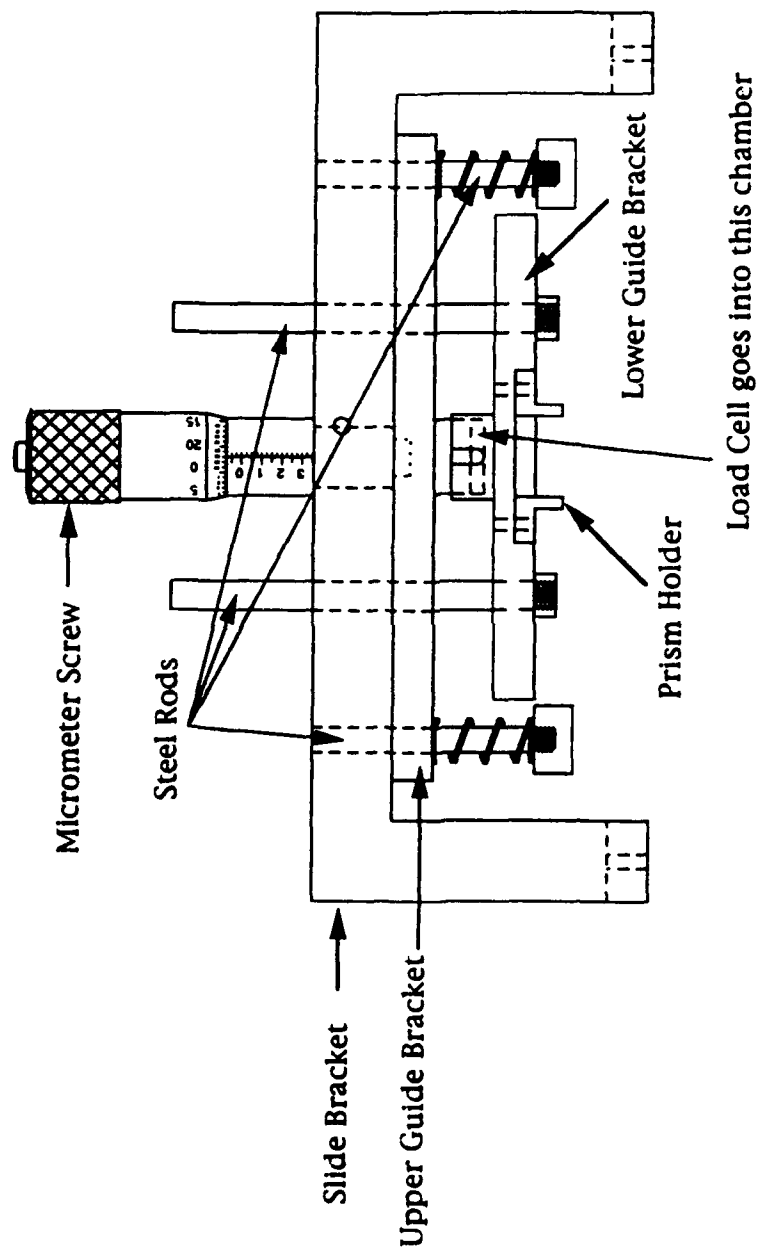


FIGURE 66 - Bracket Assembly

Wave Guide Stage Assembly	
Bracket Assembly	
Front View	
Tom Kensky WLM/PO	Not to Scale
	29 Jul 92

APPENDIX C - SOFTWARE LISTING

```

10  !*****
20  !** OPTICAL WAVEGUIDE LOSS MEASUREMENT PROGRAM **
30  !** TOM KENSKY **
40  !** MATERIALS DIRECTORATE WL/MLPO WPAFB, OHIO **
50  !** VERSION 6      2 SEP 93 **
60  !*****
70  !
80  OPTION BASE 0
90  GINIT
100 GCLEAR
110 !
120 !*****
130 !** DIM ARRAYS FOR USE BY SUBROUTINES **
140 !*****
150 !
160 DIM Value$(10)[80]
170 DIM Choices$(10)[80]
180 DIM Distance$(10)[80]
190 DIM Constraints$(10)[80]
200 DIM Stage_pos$(30)
210 DIM Filename$(80)
220 DIM Steps$(3)[10]
230 !
240 !*****
250 !** SET THE ADDRESS OF THE EQUIPMENT **
260 !** MOTION CONTROLLER ADDRESS IS 16 **
270 !** HP 3457A VOLTMETER ADDRESS IS 22 **
280 !** HP 6942A MULTIPROGRAMMER ADDRESS IS 12 **
290 !*****
300 !
310 ON ERROR GOTO 330
320 CSIZE 5
330 CLEAR SCREEN
340 MOVE 15,80
350 LABEL *****
360 LABEL *** SELECT THE BASE ADDRESS FOR ***
370 LABEL *** THE EQUIPMENT (i.e. which ***
380 LABEL *** optical table are you on?) ***
390 LABEL *****
400 INPUT "ENTER THE BASE ADDRESS: (7 OR 8)",Address$
410 IF VAL(Address$)=7 THEN
420 ASSIGN @Daedal TO 716
430 ASSIGN @Voltmeter TO 722
440 ASSIGN @Multi TO 712
450 GOTO 540
460 END IF
470 IF VAL(Address$)=8 THEN
480 ASSIGN @Daedal TO 816
490 ASSIGN @Voltmeter TO 822
500 ASSIGN @Multi TO 812
510 GOTO 540
520 END IF
530 GOTO 330
540 OFF ERROR
550 !

```

```

560 !*****
570 !** PROMPT USER FOR CHOICE OF **
580 !** 3-PRISM OR OUT-OF-PLANE **
590 !** TECHNIQUES **
600 !*****
610 !
620 ON ERROR GOTO 630
630 CLEAR SCREEN
640 MOVE 15,80
650 LABEL *****
660 LABEL *** ARE YOU DOING OUT OF PLANE ***
670 LABEL *** MEASUREMENTS? ***
680 LABEL *****
690 INPUT "ENTER 'Y' OR 'N'",Out_of_plane$
700 IF Out_of_plane$="Y" OR Out_of_plane$="y" THEN
710 Out_of_plane=1
720 ELSE
730 Out_of_plane=0
740 END IF
750 CLEAR SCREEN
760 OFF ERROR
770 !
780 !*****
790 !** CAN'T USE THE STEPPER MOTOR FOR **
800 !** THE MEASUREMENT ARM WHEN DOING **
810 !** OUT-OF-PLANE MEASUREMENTS **
820 !*****
830 !
840 IF Out_of_plane=1 THEN
850 Use_motor=0
860 GOTO 1090
870 END IF
880 !
890 !*****
900 !** PROMPT USER FOR CHOICE OF USING **
910 !** THE STEPPER MOTOR FOR DRIVING **
920 !** THE MEASUREMENT ARM **
930 !*****
940 !
950 ON ERROR GOTO 960
960 CLEAR SCREEN
970 MOVE 15,80
980 LABEL *****
990 LABEL *** ARE YOU USING THE STEPPER ***
1000 LABEL *** MOTOR FOR THE MEASUREMENT ***
1010 LABEL *** ARM? ***
1020 LABEL *****
1030 INPUT "ENTER 'Y' OR 'N'",Use_motor$
1040 IF Use_motor$="Y" OR Use_motor$="y" THEN
1050 Use_motor=1
1060 ELSE
1070 Use_motor=0
1080 END IF
1090 CLEAR SCREEN
1100 OFF ERROR
1110 !
1120 !*****
1130 !** INITIALIZE DAEDAL MOTION CONTROLLER: **

```

```

1140  !*** ENABLE IEEE-488,NORMAL MODE,SET DISPLAY TO ZERO **
1150  !*** ACCELERATION=5 REVS/SEC/SEC, VELOCITY=1 REV/SEC **
1160  !*** COUNTER ZERO RESET **
1170  !*****
1180  !
1190  OUTPUT @Daedal USING "#,K";"E MN DA A5.0 V1 X0 ",END
1200  !
1210  !*****
1220  !*** INITIALIZE HP 3457A VOLTMETER: DCV,AUTO,INTERNAL TRIGGER, **
1230  !*** 5 1/2 DIGITS,SELECT HP 44492 AS INPUT,FIX INPUT Z TO 10M **
1240  !*** FOR ALL RANGES OF DCV **
1250  !*****
1260  !
1270  OUTPUT @Voltmeter;"DCV AUTO,.01"
1280  OUTPUT @Voltmeter;"TRIG AUTO"
1290  OUTPUT @Voltmeter;"TERM REAR"
1300  OUTPUT @Voltmeter;"FIXEDZ ON"
1310  !
1320  !*****
1330  !*** INITIALIZE VALUES FOR SCROLL MENU **
1340  !*** MANUAL ADJUSTMENT OF STAGE POSITION **
1350  !*****
1360  !
1370  Choices$(0)="10,000 STEP MOVEMENT"
1380  Choices$(1)="1,000 STEP MOVEMENT"
1390  Choices$(2)="100 STEP MOVEMENT"
1400  Choices$(3)="10 STEP MOVEMENT"
1410  Choices$(4)="1 STEP MOVEMENT"
1420  Distance$(0)="10000"
1430  Distance$(1)="1000"
1440  Distance$(2)="100"
1450  Distance$(3)="10"
1460  Distance$(4)="1"
1470  Num_of_choices=5
1480  Stage_pos$="0"
1490  !
1500  !*****
1510  !*** ALLOW MONITORING OF THE LOAD CELLS **
1520  !*** AND DETECTORS TO SETUP THE EXPERIMENT **
1530  !*** ALLOW ADJUSTMENT OF THE STAGE POSITION **
1540  !*****
1550  !
1560  DIM Message$(50)
1570  ON KEY 7 LABEL "" GOTO 1770
1580  ON KEY 8 LABEL "" GOTO 1770
1590  ON KEY 1 LABEL "CELL 1 F1" GOTO 1780
1600  ON KEY 2 LABEL "CELL 2 F2" GOTO 1850
1610  ON KEY 3 LABEL "CELL 3 F3" GOTO 1920
1620  ON KEY 4 LABEL "EXIT P. F4" GOTO 1990
1630  ON KEY 5 LABEL "MEAS P. F5" GOTO 2060
1640  ON KEY 6 LABEL "STAGE F6" GOTO 2480
1650  ON KEY 7 LABEL "PROCEED F7" GOTO 2510
1660  CLEAR SCREEN
1670  MOVE 10,80
1680  LABEL "*****"
1690  LABEL "*** PRE-EXPERIMENT SETUP SECTION ***"
1700  LABEL "***"
1710  LABEL "*** ADJUST LOAD CELLS AND DETECTORS ***"

```

```

1720 LABEL *** ***
1730 LABEL *** CHOOSE AN ITEM USING THE SOFTKEYS ***
1740 LABEL *** OR CONTINUE WITH THE EXPERIMENT ***
1750 LABEL *** BY PRESSING 'PROCEED' ***
1760 LABEL *****
1770 GOTO 1770
1780 Message$="*** ADJUST PRISM 1 ***"
1790 CLEAR SCREEN
1800 CSIZE 5
1810 Multiplier=10
1820 Tail$=" lbs"
1830 OUTPUT @Voltmeter;"CHAN 0"
1840 GOTO 2120
1850 Message$="*** ADJUST PRISM 2 ***"
1860 CLEAR SCREEN
1870 CSIZE 5
1880 Multiplier=10
1890 Tail$=" lbs"
1900 OUTPUT @Voltmeter;"CHAN 1"
1910 GOTO 2120
1920 Message$="*** ADJUST PRISM 3 ***"
1930 CLEAR SCREEN
1940 CSIZE 5
1950 Multiplier=10
1960 Tail$=" lbs"
1970 OUTPUT @Voltmeter;"CHAN 2"
1980 GOTO 2120
1990 Message$="*** EXIT PRISM INTENSITY ***"
2000 CLEAR SCREEN
2010 CSIZE 5
2020 Multiplier=1
2030 Tail$=" V"
2040 OUTPUT @Voltmeter;"CHAN 3"
2050 GOTO 2120
2060 Message$="*** MEAS PRISM INTENSITY ***"
2070 CLEAR SCREEN
2080 CSIZE 5
2090 Multiplier=1
2100 Tail$=" V"
2110 OUTPUT @Voltmeter;"CHAN 4"
2120 MOVE 10,90
2130 LABEL *****
2140 LABEL Message$
2150 LABEL *****
2160 LABEL
2170 LABEL " PRESS ANY KEY TO CONTINUE"
2180 LABEL "AFTER ADJUSTMENT OR MONITORING "
2190 !
2200 !*****
2210 !** ON SCREEN MONITOR OF MEASURED VALUE FROM VOLTMETER **
2220 !*****
2230 !
2240 ON KBD GOTO 2380
2250 MOVE 5,50
2260 LABEL "YOUR CHOSEN ITEM HAS THIS CURRENT VALUE:"
2270 CSIZE 15
2280 Old_imp_value$=Imp_value$
2290 ENTER @Voltmeter;Imp_value

```

```

2300 Imp_value$=VAL$(Imp_value*Multiplier)&Tail$
2310 MOVE 5,30
2320 PEN -1
2330 LABEL Old_imp_value$
2340 MOVE 5,30
2350 PEN 1
2360 LABEL Imp_value$
2370 GOTO 2280
2380 OFF KBD
2390 CLEAR SCREEN
2400 CSIZE 5
2410 GOTO 1660
2420 !
2430 !*****
2440 !** CALL SUBROUTINE THAT ALLOWS 'MANUAL' POSITIONING **
2450 !** OF THE WAVEGUIDE STAGE **
2460 !*****
2470 !
2480 CALL
Manual(Num_of_choices,Choices$(*),Distance$(*),@Daedal,Stage_pos$)
2490 !
2500 GOTO 1660
2510 OFF KBD
2520 OFF KEY
2530 CLEAR SCREEN
2540 CSIZE 5
2550 !
2560 !*****
2570 !** CALL SUBROUTINE THAT ALLOWS 'MANUAL' POSITIONING **
2580 !** OF THE WAVEGUIDE STAGE (INITIALIZE POSITION) **
2590 !*****
2600 !
2610 CALL
Manual(Num_of_choices,Choices$(*),Distance$(*),@Daedal,Stage_pos$)
2620 !
2630 IF Use_motor=0 THEN GOTO 3160 ! SKIP WHEN NOT USING HURST
2640 !
2650 !*****
2660 !** CALL SUBROUTINE THAT ADJUSTS THE PRESSURE **
2670 !** ON THE MEASUREMENT ARM PRISM IF THE HURST **
2680 !** STEPPER MOTOR IS BEING USED **
2690 !*****
2700 !
2710 Num_of_choices=4
2720 Choices$(0)="1000 STEPS"
2730 Choices$(1)="100 STEPS"
2740 Choices$(2)="10 STEPS"
2750 Choices$(3)="1 STEP"
2760 Steps$(0)="1000"
2770 Steps$(1)="100"
2780 Steps$(2)="10"
2790 Steps$(3)="1"
2800 Total_steps=0
2810 !
2820 CALL
Hurst(Num_of_choices,Choices$(*),Steps$(*),@Multi,@Voltmeter,Initial_steps,
Pressure2)
2830 !

```



```

2840 !*****
2850 !** SET THE TARGET PRESSURE FOR THE AUTOMATED **
2860 !** MEASUREMENTS **
2870 !*****
2880 !
2890 Target_press=Pressure2
2900 !
2910 !*****
2920 !** REDUCE INITIAL NUMBER OF STEPS SLIGHTLY **
2930 !** TO PREVENT OVER PRESSURE **
2940 !*****
2950 !
2960 IF Initial_steps<50 THEN GOTO 3160
2970 IF Initial_steps>5000 THEN
2980             Initial_steps=Initial_steps-100
2990             ELSE
3000             Initial_steps=Initial_steps-50
3010 END IF
3020 !
3030 !*****
3040 !** END OF MANUAL SETUP **
3050 !*****
3060 !
3070 !*****
3080 !** BEGIN EXPERIMENT **
3090 !*****
3100 !
3110 !*****
3120 !** INITIALIZE VALUES FOR SCROLL MENU **
3130 !** EXPERIMENT SETUP VALUES **
3140 !*****
3150 !
3160 Choices$(0)="MOVE TOWARD OR AWAY FROM MOTOR? (T/A)"
3170 Choices$(1)="TRAVEL INCREMENT IN mm (.1 - 10)"
3180 Choices$(2)="TOTAL MEAS. DIST. IN mm (1<D<100)"
3190 Choices$(3)="ENTER THE FILENAME"
3200 Choices$(4)="EXIT"
3210 Num_of_choices=5
3220 Constraints$(0)="T,0,0,T,A,!"
3230 Constraints$(1)="N,10,.1,0,0,!"
3240 Constraints$(2)="N,100,1,0,0,!"
3250 Constraints$(3)="T,0,0,,!"
3260 !
3270 !*****
3280 !** CALL SUBROUTINE FOR INPUTING EXPERIMENT PARAMETERS **
3290 !*****
3300 !
3310 CALL Chooser(Num_of_choices,Choices$(*),Constraints$(*),Value$(*))
3320 CLEAR SCREEN
3330 Filename$=Value$(3)
3340 !
3350 !*****
3360 !** RESET POSITION COUNTER AND DISPLAY TO ZERO **
3370 !*****
3380 !
3390 OUTPUT @Daedal USING "#,K";"X0 DA ",END
3400 !
3410 !*****

```

```

3420  !** CONVERSION AND PARAMETER SETUP ROUTINES **
3430  !*****
3440  !
3450  !*****
3460  !** SET COMMAND FOR CONTROLLER FOR FORWARD OR **
3470  !** REVERSE TRAVEL DIRECTION **
3480  !*****
3490  !
3500  IF Value$(0)="A" THEN
3510      Direction$=""
3520  ELSE
3530      Direction$="-"
3540  END IF
3550  !
3560  !*****
3570  !** CONVERT MILLIMETERS TO INCHES **
3580  !** GET MOTOR STEPS PER INCREMENT **
3590  !*****
3600  !
3610  Increment=VAL(Value$(1))/25.4
3620  Total_dist=VAL(Value$(2))/25.4
3630  Inc_step=INT(Increment/.00002)
3640  Step_count=INT(Total_dist/Increment)
3650  !
3660  !*****
3670  !** INFORM USER OF THE NUMBER OF MEASUREMENT STEPS **
3680  !*****
3690  !
3700  PRINT "THE TOTAL NUMBER OF MEASUREMENT STEPS WILL BE ";Step_count
3710  WAIT 2
3720  CLEAR SCREEN
3730  !
3740  !*****
3750  !** DIMENSION AN ARRAY FOR STORING THE DATA **
3760  !*****
3770  !
3780  ALLOCATE Datums(Step_count-1,8)
3790  !
3800  !*****
3810  !** INFORM USER THAT MEASUREMENTS WILL BEGIN **
3820  !*****
3830  !
3840  MOVE 15,70
3850  LABEL *****
3860  LABEL *** MEASUREMENT WILL NOW BEGIN ***
3870  LABEL *****
3880  WAIT 2
3890  CLEAR SCREEN
3900  !
3910  !*****
3920  !** GENERATE COMMAND STRING FOR TRAVEL DIRECTION **
3930  !** AND INCREMENTAL DISTANCE STEP. THIS MOVE IS **
3940  !** EXECUTED IN THE UPCOMING FOR/NEXT LOOP **
3950  !*****
3960  !
3970  Command$="D"&Direction$&VAL$(Inc_step)&" "
3980  !
3990  !*****

```

```

4000  !** THIS SENDS THE COMMAND TO THE CONTROLLER **
4010  !** NO ACTUAL MOVE IS DONE YET THOUGH      **
4020  !*****
4030  !
4040  OUTPUT @Daedal USING "#,K";Command$,END
4050  !
4060  !*****
4070  !** INITIALIZE STAGE POSITION VARIABLE TO ZERO **
4080  !*****
4090  !
4100  Position=0
4110  !
4120  !*****
4130  !** MOVE/MEASUREMENT FOR/NEXT LOOP **
4140  !*****
4150  !
4160  FOR I=0 TO Step_count-1
4170  IF Out_of_plane=1 THEN GOTO 4690 ! SKIP FOR OUT OF PLANE
4180  IF Use_motor=1 THEN GOTO 4540 ! SKIP WHEN USING HURST MOTOR
4190  !
4200  MOVE 15,70
4210  LABEL *****
4220  LABEL *** TIGHTEN MEASUREMENT PRISM ***
4230  LABEL *****
4240  LABEL
4250  LABEL "PRESS ANY KEY TO CONTINUE AFTER"
4260  LABEL "AFTER PRISM PRESSURE STABILIZES"
4270  !
4280  !*****
4290  !** ON SCREEN MONITOR OF MEASUREMENT PRISM PRESSURE **
4300  !*****
4310  !
4320  ON KBD GOTO 4470
4330  OUTPUT @Voltmeter;"CHAN 1"
4340  CSIZE 15
4350  Old_pressure2=Pressure2
4360  Old_pressure2$=VAL$(Old_pressure2)&" lbs"
4370  ENTER @Voltmeter;Pressure2
4380  Pressure2=10*Pressure2
4390  Pressure2$=VAL$(Pressure2)&" lbs"
4400  PEN -1
4410  MOVE 5,30
4420  LABEL Old_pressure2$
4430  PEN 1
4440  MOVE 5,30
4450  LABEL Pressure2$
4460  GOTO 4350
4470  OFF KBD
4480  GOTO 4690
4490  !
4500  !*****
4510  !** STEPPER MOTOR ROUTINE GOES HERE **
4520  !*****
4530  !
4540  Total_steps=Initial_steps
4550  OUTPUT @Voltmeter;"CHAN 1"
4560  OUTPUT @Multi;"WF,8.1,0,8.2,5000T,OP,8,"&VAL$(Initial_steps)&"T"
4570  WAIT .005*Initial_steps ! WAIT UNTIL FINISHED

```

```

4580 ENTER @Voltmeter;Pressure2 !GET NEW PRESSURE
4590 !
4600 IF Pressure2>Target_press THEN
4610 GOTO 4690
4620 ELSE
4630 OUTPUT @Multi;"WF,8.1,0,8.2,5000T,OP,8,10T"
4640 WAIT .05 ! WAIT UNTIL FINISHED
4650 Total_steps=Total_steps+10
4660 GOTO 4580
4670 END IF
4680 !
4690 CSIZE 5
4700 CLEAR SCREEN
4710 !
4720 !*****
4730 !** TAKE MEASUREMENTS **
4740 !*****
4750 !
4760 OUTPUT @Voltmeter;"CHAN 3"
4770 PRINT "Reading Exit Prism Intensity..."
4780 ENTER @Voltmeter;Exit_prism
4790 DISP "EXIT PRISM READING WAS ";Exit_prism
4800 WAIT 1
4810 OUTPUT @Voltmeter;"CHAN 4"
4820 PRINT " Reading Measurement Prism Intensity..."
4830 ENTER @Voltmeter;Meas_prism
4840 DISP "MEASUREMENT PRISM READING WAS ";Meas_prism
4850 WAIT 1
4860 OUTPUT @Voltmeter;"CHAN 0"
4870 PRINT " Reading Load Cell 1 Pressure..."
4880 ENTER @Voltmeter;Pressure1
4890 DISP "LOAD CELL 1 READING WAS ";Pressure1
4900 WAIT 1
4910 !
4920 IF Out_of_plane=1 THEN GOTO 4990 ! SKIP FOR OUT OF PLANE
4930 !
4940 OUTPUT @Voltmeter;"CHAN 1"
4950 PRINT " Reading Load Cell 2 Pressure..."
4960 ENTER @Voltmeter;Pressure2
4970 DISP "LOAD CELL 2 READING WAS ";Pressure2
4980 WAIT 1
4990 OUTPUT @Voltmeter;"CHAN 2"
5000 PRINT " Reading Load Cell 3 Pressure..."
5010 ENTER @Voltmeter;Pressure3
5020 DISP "LOAD CELL 3 READING WAS ";Pressure3
5030 WAIT 1
5040 Datums(I,0)=ABS(Position*.00002*25.4)! STAGE POSITION
5050 Datums(I,1)=Exit_prism! EXIT PRISM
5060 Datums(I,2)=Meas_prism! MEAS PRISM
5070 Datums(I,3)=10*Pressure1! LDCELL1
5080 Datums(I,4)=10*Pressure2! LDCELL2
5090 Datums(I,5)=10*Pressure3! LDCELL3
5100 CLEAR SCREEN
5110 PRINT "THE LAST MEASUREMENT POSITION WAS ";Datums(I,0);" mm"
5120 !
5130 !*****
5140 !** END OF TAKE MEASUREMENTS SECTION **
5150 !*****

```

```

5160 !
5170 IF Out_of_plane=1 THEN GOTO 5720 ! SKIP FOR OUT OF PLANE
5180 IF Use_motor=1 THEN GOTO 5690 ! SKIP WHEN USING HURST MOTOR
5190 PEN 1
5200 MOVE 15,70
5210 LABEL *****
5220 LABEL *** LOOSEN MEASUREMENT PRISM ***
5230 LABEL *****
5240 LABEL
5250 LABEL "PRESS ANY KEY TO CONTINUE AFTER"
5260 LABEL "THE PRISM IS OFF THE SAMPLE"
5270 !
5280 !*****
5290 !** ON SCREEN MONITOR OF MEASUREMENT PRISM PRESSURE **
5300 !*****
5310 !
5320 ON KBD GOTO 5530
5330 OUTPUT @Voltmeter;"CHAN 1"
5340 CSIZE 15
5350 Old_no_press=No_press
5360 Old_no_press$=VAL$(Old_no_press)&" lbs"
5370 ENTER @Voltmeter;No_press
5380 No_press=10*No_press
5390 No_press$=VAL$(No_press)&" lbs"
5400 PEN -1
5410 MOVE 5,30
5420 LABEL Old_no_press$
5430 PEN 1
5440 MOVE 5,30
5450 LABEL No_press$
5460 GOTO 5350
5470 !
5480 !*****
5490 !** NO MOVEMENT ALLOWED UNTIL PRISM **
5500 !** IS OFF OF THE SAMPLE **
5510 !*****
5520 !
5530 IF No_press>.08 THEN
5540     PEN -1
5550     MOVE 5,30
5560     LABEL Old_no_press$
5570     GOTO 5350
5580 END IF
5590 OFF KBD
5600 PEN -1
5610 MOVE 5,30
5620 LABEL No_press$
5630 GOTO 5720
5640 !
5650 !*****
5660 !** RAISE HURST MOTOR ROUTINE HERE **
5670 !*****
5680 !
5690 OUTPUT @Multi;"WF,8.1,0,8.2,5000T,OP,8,-"&VAL$(Total_steps)&"T"
5700 WAIT .005*Total_steps
5710 !
5720 PEN 1
5730 CSIZE 5

```

```

5740 CLEAR SCREEN
5750 !
5760 !*****
5770 !** READ EXIT PRISM QUIESCENT INTENSITY **
5780 !*****
5790 !
5800 OUTPUT @Voltmeter;"CHAN 3"
5810 ENTER @Voltmeter;Exit_prism
5820 Datums(I,6)-Exit_prism! EXIT PRISM QUIESCENT
5830 !
5840 !*****
5850 !** CALCULATE (P3o*P2)/(P3o-P3) AND ITS LOG **
5860 !*****
5870 !
5880 Datums(I,7)=((Datums(I,6)*Datums(I,2))/(Datums(I,6)-Datums(I,1)))
5890 ON ERROR GOTO 5920 !CAN'T TAKE LOG OF NEG NUMBER
5900 Datums(I,8)=LGT(Datums(I,7))
5910 GOTO 5930
5920 Datums(I,8)=0
5930 OFF ERROR
5940 !
5950 !*****
5960 !** PREVENTS LAST MOVE COMMAND **
5970 !*****
5980 !
5990 IF I=Step_count-1 THEN GOTO 6210
6000 OUTPUT @Daedal USING "#,K";"G ",END!** MOVE COMMAND **
6010 !
6020 !*****
6030 !** WAIT UNTIL MOVE IS COMPLETE **
6040 !*****
6050 !
6060 IF SPOLL(@Daedal)=1 THEN GOTO 6140
6070 GOTO 6060
6080 !
6090 !*****
6100 !** REQUEST AND RECEIVE POSITION INFO **
6110 !** FROM THE STAGE CONTROLLER **
6120 !*****
6130 !
6140 OUTPUT @Daedal USING "#,K";"X1 ",END
6150 Test=SPOLL(@Daedal)
6160 IF Test>8 THEN GOTO 6180!GET FROM CONTROLLER?
6170 GOTO 6150
6180 WAIT .5
6190 ENTER @Daedal;Position$!RECEIVE POSITION
6200 Position=VAL(Position$)
6210 NEXT I
6220 !
6230 !*****
6240 !** END OF ACQUISITION FOR/NEXT LOOP **
6250 !*****
6260 !
6270 CLEAR SCREEN
6280 !
6290 !*****
6300 !** DISABLE IEEE-488 FOR CONTROLLER **
6310 !*****

```

```

6320 !
6330 OUTPUT @Daedal USING "#,K";"F ",END
6340 !
6350 !*****
6360 !** CONVERT AND STORE DATA ON THE HARD DISK **
6370 !*****
6380 !
6390 CALL Data_converter(Datums(*),Filename$)
6400 !
6410 !*****
6420 !** END OF DATA STORAGE **
6430 !*****
6440 !
6450 END
6460 !
6470 !!!!!!!!!!!!!!!!!!!!!!!!!!!!!
6480 !** END OF PROGRAM **
6490 !!!!!!!!!!!!!!!!!!!!!!!!!!!!!
6500 !
6510 !
6520 !!!!!!!!!!!!!!!!!!!!!!!!!!!!!
6530 !** BEGIN SUBROUTINES **
6540 !!!!!!!!!!!!!!!!!!!!!!!!!!!!!
6550 !
6560 SUB
Manual (Num_of_choices,Choices$(*),Distance$(*),@Daedal,Stage_pos$)
6570 !
6580 !*****
6590 !** THIS SUBROUTINE ALLOWS MENU-LIKE CONTROL OF THE DAEDAL **
6600 !** MOTION CONTROLLER AND THE RAIL TABLE. IT IS USED TO **
6610 !** 'MANUALLY' POSITION THE RAIL TABLE BEFORE BEGINNING **
6620 !** THE EXPERIMENT **
6630 !*****
6640 !
6650 !** VARIABLE DESCRIPTIONS: **
6660 !** **
6670 !** Num_of_choices - THIS IS THE TOTAL NUMBER OF ITEMS **
6680 !** LISTED IN THE MENU ON THE SCREEN **
6690 !
6700 !** Choices$(*) - THIS IS A SERIES OF STRINGS CONTAINING **
6710 !** THE TEXT ASKING FOR INPUT INFORMATION **
6720 !** e.g. "10,000 STEP MOVEMENT" **
6730 !** OPTION BASE 0 MUST BE USED e.g. WHEN **
6740 !** Num_of_choices=3 then Choices$(*) MUST **
6750 !** BE NUMBERED Choices$(0),Choices$(1),AND **
6760 !** Choices$(2) **
6770 !** **
6780 !** Distance$(*) - THIS SET OF STRINGS CONTAINS THE **
6790 !** NUMBER OF STEPS THAT WILL BE MOVED **
6800 !** WHEN THE LEFT OR RIGHT ARROW KEY IS **
6810 !** PRESSED **
6820 !** **
6830 !** @DAEDAL - THIS IS THE HPIB ADDRESS OF THE MOTION **
6840 !** CONTROLLER. THIS IS ASSIGNED AT THE **
6850 !** BEGINNING OF THE PROGRAM **
6860 !** **
6870 !** Stage_pos$ - THIS IS THE CURRENT POSITION OF THE **
6880 !** STAGE. WHEN THIS PROGRAM IS STARTED **

```

```

6890 !**          THE CURRENT POSITION OF THE STAGE IS          **
6900 !**          TAKEN AS ZERO.  THIS VARIABLE WILL GIVE      **
6910 !**          THE USER THE RELATIVE POSITION SINCE          **
6920 !**          BEGINNING THE PROGRAM                        **
6930 !**                                                         **
6940 !*****
6950 !
6960 !*****
6970 !** THE NEXT 4 LINES CLEAR THE SCREEN, SET THE STARTING **
6980 !** POINT FOR LABELS, SET THE PEN TO WRITE AND SET THE **
6990 !** CHARACTER SIZE                                         **
7000 !*****
7010 !
7020 CLEAR SCREEN
7030 PEN 1
7040 CSIZE 4, .5
7050 !
7060 !*****
7070 !** THIS LINE MAKES THE CHOOSING CURSOR A WHITE BLOCK **
7080 !*****
7090 !
7100 Cursor$=CHR$(127)
7110 !
7120 !*****
7130 !** THE FOR NEXT LOOP PUTS THE CHOICES ON THE SCREEN **
7140 !*****
7150 !
7160 FOR I=0 TO Num_of_choices-1
7170 MOVE 10,95-5*I
7180 LABEL Choices$(I)
7190 NEXT I
7200 !
7210 !*****
7220 !** THE NEXT 3 LINES PLACES THE CURSOR BESIDE THE 1st CHOICE **
7230 !*****
7240 !
7250 MOVE 5,95
7260 I=0
7270 LABEL Cursor$
7280 !
7290 !*****
7300 !** THE NEXT TWO LINES PRINTS THE CURRENT POSITION OF THE STAGE **
7310 !*****
7320 !
7330 MOVE 10,20
7340 LABEL "THE CURRENT POSITION IS ";Stage_pos$
7350 !
7360 !*****
7370 !** THE NEXT 4 LINES PRINTS AN OPERATING INSTRUCTION ON THE SCREEN **
7380 !*****
7390 !
7400 MOVE 10,30
7410 LABEL "PRESS RETURN WHEN MANUAL ADJUSTMENT IS COMPLETE"
7420 MOVE 10,35
7430 LABEL "USE LEFT/RIGHT ARROWS TO MOVE MOTOR"
7440 MOVE 10,40
7450 LABEL "USE UP/DOWN ARROWS TO SCROLL MENU"
7460 !

```



```

7470 !*****
7480 !** WHEN A KEY IS STRUCK GO TO THE MOVE CURSOR ROUTINE **
7490 !*****
7500 !
7510 Diddle_loop: ON KBD GOTO Movement
7520         GOTO 7520
7530 !
7540 !*****
7550 !** MOVE CURSOR ROUTINE **
7560 !*****
7570 !
7580 !*****
7590 !** THIS ROUTINE ONLY TAKES ACTION WHEN THE UP,DOWN OR **
7600 !** RETURN KEY IS PRESSED. GO TO Up ON UP KEY, GO TO **
7610 !** Down ON DOWN KEY, GO TO Take_data ON RETURN **
7620 !*****
7630 !
7640 Movement: !
7650         Where$=KBD$
7660         OFF KBD
7670         IF Where$=CHR$(255)&"^" THEN Up
7680         IF Where$=CHR$(255)&"V" THEN Down
7690         IF Where$=CHR$(255)&"<" THEN Move_stage_lft
7700         IF Where$=CHR$(255)&">" THEN Move_stage_rgt
7710         IF Where$=CHR$(255)&"E" THEN Finished
7720 GOTO Diddle_loop
7730 !
7740 !*****
7750 !** END OF MOVE CURSOR ROUTINE **
7760 !*****
7770 !
7780 !*****
7790 !** UP MOVEMENT ROUTINE **
7800 !*****
7810 !
7820 !*****
7830 !** THIS SCROLLS THE CURSOR UP **
7840 !*****
7850 !
7860 Up: !
7870 PEN -1
7880 MOVE 5,95-5*I
7890 LABEL Cursor$
7900 IF I=0 THEN
7910         I=Num_of_choices-1
7920     ELSE
7930         I=I-1
7940 END IF
7950 PEN 1
7960 MOVE 5,95-5*I
7970 LABEL Cursor$
7980 GOTO Diddle_loop
7990 !
8000 !*****
8010 !** END OF UP MOVEMENT ROUTINE **
8020 !*****
8030 !
8040 !*****

```

```

8050  !** DOWN MOVEMENT ROUTINE  **
8060  !*****
8070  !
8080  !*****
8090  !** THIS SCROLLS THE CURSOR DOWN **
8100  !*****
8110  !
8120  Down: !
8130  PEN -1
8140  MOVE 5,95-5*I
8150  LABEL Cursor$
8160  IF I=Num_of_choices-1 THEN
8170  I=0
8180  ELSE
8190  I=I+1
8200  END IF
8210  PEN 1
8220  MOVE 5,95-5*I
8230  LABEL Cursor$
8240  GOTO Diddle_loop
8250  !
8260  !*****
8270  !** END OF DOWN MOVEMENT ROUTINE  **
8280  !*****
8290  !
8300  !*****
8310  !** BEGIN STAGE MOVEMENT ROUTINES **
8320  !*****
8330  !
8340  !*****
8350  !** THIS SUBROUTINE MOVES THE RAIL TABLE STAGE TO  **
8360  !** THE LEFT (TOWARD THE STEPPER MOTOR) THE NUMBER **
8370  !** OF STEPS INDICATED BY Distance$(I).  THE **
8380  !** COMPUTER THEN POLLS THE MOTION CONTROLLER TO **
8390  !** DETERMINE WHEN THE MOVE HAS BEEN COMPLETED. **
8400  !** AFTER THE MOVE IS COMPLETE THE **
8410  !** COMPUTER REQUESTS THE CURRENT RELATIVE **
8420  !** POSITION OF THE STAGE AND PRINTS IT ON THE **
8430  !** SCREEN **
8440  !*****
8450  !
8460  Move_stage_lft: !
8470  !
8480  !*****
8490  !** THE OUTPUT STATEMENT PERFORMS THE FOLLOWING: '#,K' IN USING **
8500  !** SUPPRESSES EOL AT THE END OF THE COMMAND AND STRIPS BLANKS **
8510  !** FROM ANY CHARACTERS, THE CHARACTER STRING SENT IS **
8520  !** 'D-XXXXXXX G ' WHERE XXXXXXXX IS A NUMBER. THE ',END' IS **
8530  !** USED TO SUPPRESS EOL WHEN THERE IS NO DATA SENT AND TO SEND **
8540  !** THE END-OR-IDENTIFY WHEN A COMMAND IS SENT.  SEE PAGE 450 **
8550  !** OF THE BASIC 5.0/5.1 LANGUAGE REFERENCE VOL. 2:O-Z FOR AN **
8560  !** EQUALLY USELESS EXPLANATION.  THIS IS ALL DUE **
8570  !** TO DAEDAL'S PISS-POOR IMPLEMENTATION OF THE GPIB COMMAND **
8580  !** SET **
8590  !*****
8600  !
8610  OUTPUT @Daedal USING "#,K";"D-"&Distance$(I)&" G ",END
8620  !

```

```

8630 !*****
8640 !** SERIAL POLL THE MOTION CONTROLLER TO DETERMINE WHEN STAGE **
8650 !** MOVEMENT IS COMPLETE. CONTROLLER WILL RETURN A 1 **
8660 !*****
8670 !
8680         Move_done=SPOLL(@Daedal)
8690         IF Move_done<>1 THEN GOTO 8680
8700 !
8710 !*****
8720 !** THIS OUTPUT STATEMENT REQUESTS THE CURRENT RELATIVE **
8730 !** POSITION OF THE STAGE FROM THE MOTION CONTROLLER **
8740 !*****
8750 !
8760         OUTPUT @Daedal USING "#,K";"X1 ",END
8770 !
8780 !*****
8790 !** SERIAL POLL THE MOTION CONTROLLER TO DETERMINE WHEN THE **
8800 !** CURRENT POSITION INFORMATION IS AVAILABLE **
8810 !*****
8820 !
8830         Answer_back=SPOLL(@Daedal)
8840         IF Answer_back<8 THEN GOTO 8830
8850 !
8860 !*****
8870 !** CLEAR THE OLD CURRENT POSITION FROM THE SCREEN THEN READ **
8880 !** THE NEW CURRENT POSITION INFORMATION AND PRINT IT ON THE **
8890 !** SCREEN **
8900 !*****
8910 !
8920         MOVE 10,20
8930         PEN -1
8940         LABEL "THE CURRENT POSITION IS ";Stage_pos$
8950         ENTER @Daedal USING "K";Stage_pos$
8960         MOVE 10,20
8970         PEN 1
8980         LABEL "THE CURRENT POSITION IS ";Stage_pos$
8990         GOTO Diddle_loop
9000 !
9010 !*****
9020 !** THIS SUBROUTINE MOVES THE RAIL TABLE STAGE TO **
9030 !** THE RIGHT (AWAY FROM THE STEPPER MOTOR) THE **
9040 !** NUMBER OF STEPS INDICATED BY Distance$(I). THE **
9050 !** COMPUTER THEN POLLS THE MOTION CONTROLLER TO **
9060 !** DETERMINE WHEN THE MOVE HAS BEEN COMPLETED. **
9070 !** AFTER THE MOVE IS COMPLETE THE **
9080 !** COMPUTER REQUESTS THE CURRENT RELATIVE **
9090 !** POSITION OF THE STAGE AND PRINTS IT ON THE **
9100 !** SCREEN **
9110 !*****
9120 !
9130 Move_stage_rgt: !
9140 !
9150 !*****
9160 !** THE OUTPUT STATEMENT PERFORMS THE FOLLOWING: '#,K' IN USING **
9170 !** SUPPRESSES EOL AT THE END OF THE COMMAND AND STRIPS BLANKS **
9180 !** FROM ANY CHARACTERS. THE CHARACTER STRING SENT IS **
9190 !** 'DXXXXXXX G ' WHERE XXXXXXXX IS A NUMBER. THE ',END' IS **
9200 !** USED TO SUPPRESS EOL WHEN THERE IS NO DATA SENT AND TO SEND **

```

```

9210  !** THE END-OR-IDENTIFY WHEN A COMMAND IS SENT.  SEE PAGE 450  **
9220  !** OF THE BASIC 5.0/5.1 LANGUAGE REFERENCE VOL. 2:0-2 FOR AN  **
9230  !** EQUALLY USELESS EXPLANATION.  THIS IS ALL DUE  **
9240  !** TO DAEDAL'S PISS-POOR IMPLEMENTATION OF THE GPIB COMMAND  **
9250  !** SET  **
9260  !*****
9270  !
9280      OUTPUT @Daedal USING "#,K";"D"&Distance$(I)&" G ",END
9290  !
9300  !*****
9310  !** SERIAL POLL THE MOTION CONTROLLER TO DETERMINE WHEN STAGE  **
9320  !** MOVEMENT IS COMPLETE.  CONTROLLER WILL RETURN A 1  **
9330  !*****
9340  !
9350      Move_done=SPOLL,@Daedal)
9360      IF Move_done<>1 THEN GOTO 9350
9370  !
9380  !*****
9390  !** THIS OUTPUT STATEMENT REQUESTS THE CURRENT RELATIVE  **
9400  !** POSITION OF THE STAGE FROM THE MOTION CONTROLLER  **
9410  !*****
9420  !
9430      OUTPUT @Daedal USING "#,K";"X1 ",END
9440  !
9450  !*****
9460  !** SERIAL POLL THE MOTION CONTROLLER TO DETERMINE WHEN THE  **
9470  !** CURRENT POSITION INFORMATION IS AVAILABLE  **
9480  !*****
9490  !
9500      Answer_back=SPOLL,@Daedal)
9510      IF Answer_back<8 THEN GOTO 9500
9520  !
9530  !*****
9540  !** CLEAR THE OLD CURRENT POSITION FROM THE SCREEN THEN READ  **
9550  !** THE NEW CURRENT POSITION INFORMATION AND PRINT IT ON THE  **
9560  !** SCREEN  **
9570  !*****
9580  !
9590      MOVE 10,20
9600      PEN -1
9610      LABEL "THE CURRENT POSITION IS ";Stage_pos$
9620      ENTER @Daedal USING "K";Stage_pos$
9630      MOVE 10,20
9640      PEN 1
9650      LABEL "THE CURRENT POSITION IS ";Stage_pos$
9660      GOTO Diddle_loop
9670  !
9680  !*****
9690  !** END STAGE MOVEMENT ROUTINES **
9700  !*****
9710  !
9720  !*****
9730  !** IF THE RETURN KEY IS PRESSED THE SUBPROGRAM TERMINATES  **
9740  !*****
9750  !
9760  Finished:
9770  SUBEND
9780  !

```

```

9790 SUB Chooser(Num_of_choices,Choices$(*),Constraints$(*),Value$(*))
9800 !*****
9810 !** THIS SUBROUTINE ALLOWS MENU-LIKE INPUT OF INFORMATION **
9820 !*****
9830 !
9840 !** VARIABLE DESCRIPTIONS: **
9850 !** **
9860 !** Num_of_choices - THIS IS THE TOTAL NUMBER OF ITEMS **
9870 !** THAT WILL REQUIRE ENTERED VALUES **
9880 !
9890 !** Choices$(*) - THIS IS A SERIES OF STRINGS CONTAINING **
9900 !** THE TEXT ASKING FOR INPUT INFORMATION **
9910 !** e.g. "ENTER THE PULSE WIDTH" **
9920 !** OPTION BASE 0 MUST BE USED e.g. WHEN **
9930 !** Num_of_choices=3 then Choices$(*) MUST **
9940 !** BE NUMBERED Choices$(0),Choices$(1),AND **
9950 !** Choices$(2) **
9960 !
9970 !** Constraints$(*) - THIS IS A SERIES OF STRINGS THAT **
9980 !** CONTAIN TESTING VALUES AND LIMITS **
9990 !** TO BE USED WHEN DETERMINING THE **
10000 !** VALIDITY OF ENTERED VALUES. THESE **
10010 !** STRINGS ARE USED TO VERIFY INPUT **
10020 !** VALUES AS NUMBER OR TEXT, WITHIN **
10030 !** HIGH AND LOW LIMITS IF A NUMBER **
10040 !** OR A LEGAL RESPONSE IF TEXT **
10050 !
10060 !** Value$(*) - THESE STRINGS CONTAIN THE ENTERED INFO **
10070 !** THAT WILL BE RETURNED TO THE MAIN PROGRAM **
10080 !*****
10090 !
10100 !*****
10110 !** Erase$ IS USED WHEN CORRECTING A MISTAKE IN **
10120 !** AN ENTERED VALUE **
10130 !*****
10140 DIM Erase${30}
10150 Erase$=""
10160 !*****
10170 !** Temp$ IS A TEMPORARY STORAGE STRING THAT IS USED **
10180 !** WHEN THE USER IS INPUTTING INFORMATION. WHEN **
10190 !** Temp$ IS COMPLETED IT IS TRANSFERRED TO Value$(I) **
10200 !*****
10210 DIM Temp${30}
10220 Temp$=""
10230 !*****
10240 !** THE NEXT 4 LINES CLEAR THE SCREEN,SET THE STARTING **
10250 !** POINT FOR LABELS,SET THE PEN TO WRITE AND SET THE **
10260 !** CHARACTER SIZE **
10270 !*****
10280 CLEAR SCREEN
10290 LOG 2
10300 PEN 1
10310 CSIZE 4,.5
10320 !*****
10330 !** THIS LINE MAKES THE CHOOSING CURSOR A WHITE BLOCK **
10340 !*****
10350 Cursor$=CHR$(127)
10360 !*****

```

```

10370 !** THE FOR NEXT LOOP PUTS THE CHOICES ON THE SCREEN **
10380 !*****
10390 FOR I=0 TO Num_of_choices-1
10400 MOVE 10,95-5*I
10410 LABEL Choices$(I)
10420 NEXT I
10430 I=0
10440 IF Value$(I)="" THEN GOTO 10520
10450 FOR I=0 TO Num_of_choices-2
10460 MOVE 85,95-5*I
10470 LABEL Value$(I)
10480 NEXT I
10490 !*****
10500 !** THE NEXT 3 LINES PLACES THE CURSOR BESIDE THE 1st CHOICE **
10510 !*****
10520 MOVE 5,95
10530 I=0
10540 LABEL Cursor$
10550 !*****
10560 !** WHEN A KEY IS STRUCK GO TO THE MOVE CURSOR ROUTINE **
10570 !*****
10580 Diddle_loop: ON KBD GOTO Movement
10590 GOTO 10590
10600 !*****
10610 !** MOVE CURSOR ROUTINE **
10620 !*****
10630 !
10640 !*****
10650 !** WHEN A KEY IS PRESSED, THIS ROUTINE DETERMINES **
10660 !** IF THE KEYSTROKE WAS AN UP OR DOWN ARROW OR IF IT **
10670 !** WAS A CHARACTER KEY. THE ARROWS MEAN MOVE THE **
10680 !** CURSOR UP OR DOWN THROUGH THE CHOICES ON THE **
10690 !** SCREEN. A CHARACTER KEY MEANS THAT INFO IS BEING **
10700 !** ENTERED. THE "DISP Where$" PLACES THE FIRST CHAR. **
10710 !** ON THE SCREEN BEFORE EXITING TO THE Take_data **
10720 !** IN ORDER TO MAKE INPUT VIEWING MORE SMOOTH **
10730 !*****
10740 Movement: !
10750 Where$=KBD$
10760 OFF KBD
10770 IF Where$=CHR$(255)&"^" THEN Up
10780 IF Where$=CHR$(255)&"V" THEN Down
10790 IF LEN(Where$)=1 THEN DISP Where$
10800 IF Where$<>" " THEN
10810 GOTO Take_data
10820 END IF
10830 GOTO Diddle_loop
10840 !*****
10850 !** END OF MOVE CURSOR ROUTINE **
10860 !*****
10870 !
10880 !*****
10890 !** UP MOVEMENT ROUTINE **
10900 !*****
10910 !
10920 !*****
10930 !** THIS SCROLLS THE CURSOR UP **
10940 !*****

```

```

10950 Up: !
10960 PEN -1
10970 MOVE 5,95-5*I
10980 LABEL Cursor$
10990 IF I=0 THEN
11000         I=Num_of_choices-1
11010     ELSE
11020         I=I-1
11030 END IF
11040 PEN 1
11050 MOVE 5,95-5*I
11060 LABEL Cursor$
11070 GOTO Diddle_loop
11080 !*****
11090 !**  END OF UP MOVEMENT ROUTINE  **
11100 !*****
11110 !
11120 !*****
11130 !**  DOWN MOVEMENT ROUTINE  **
11140 !*****
11150 !
11160 !*****
11170 !** THIS SCROLLS THE CURSOR DOWN **
11180 !*****
11190 Down: !
11200 PEN -1
11210 MOVE 5,95-5*I
11220 LABEL Cursor$
11230 IF I=Num_of_choices-1 THEN
11240         I=0
11250     ELSE
11260         I=I+1
11270 END IF
11280 PEN 1
11290 MOVE 5,95-5*I
11300 LABEL Cursor$
11310 GOTO Diddle_loop
11320 !*****
11330 !**  END OF DOWN MOVEMENT ROUTINE  **
11340 !*****
11350 !
11360 !*****
11370 !**          TAKE DATA ROUTINE          **
11380 !*****
11390 !*****
11400 !** THIS LOOP TAKES YOUR ENTRY FOR A      **
11410 !** PARTICULAR PARAMETER AND DETERMINES  **
11420 !** IF IT IS VALID GIVEN THE CONSTRAINTS **
11430 !** SET FORTH IN THE CONSTRAINTS$ STRING **
11440 !*****
11450 !
11460 !*****
11470 !** CHECKS TO SEE IF "EXIT" WAS CHOSEN **
11480 !*****
11490 Take_data: IF I=Num_of_choices-1 THEN
11500         GOTO Done
11510 END IF
11520 !*****

```

```

11530 !** THE FIRST CHARACTER OF THE Temp$ STRING **
11540 !** IS TAKEN FROM THE Where$ STRING SINCE **
11550 !** THIS WAS THE FIRST CHARACTER PRESSED **
11560 !** OTHER THAN AN UP OR DOWN ARROW KEY **
11570 !** Where$ IS THEN CLEARED **
11580 !*****
11590 Temp$=Where$
11600 Where$=""
11610 !*****
11620 !** SET PEN TO ERASE,ERASE CURSOR,SET PEN TO WRITE, **
11630 !** MOVE TO THE LOCATION WHERE THE VALID ENTRY WILL **
11640 !** BE DISPLAYED **
11650 !*****
11660 PEN -1
11670 LABEL Cursor$
11680 PEN 1
11690 MOVE 85,95-5*I
11700 !*****
11710 !** GO TO THE SUBROUTINE THAT STRIPS THE CONSTRAINT **
11720 !** PARAMETERS FROM THE PROPER CONSTRAINT$ STRING **
11730 !** FOR THE CHOSEN ENTRY ITEM **
11740 !*****
11750 GOSUB Extract
11760 !*****
11770 !** UPDATE THE ERASE STRING,GENERATE AN ATTENTION TONE **
11780 !** AND REQUEST AN INPUT **
11790 !*****
11800 Erase$=Value$(I)
11810 ON KBD GOTO Build_string
11820 GOTO 11820
11830 Build_string:
11840 Char$=KBD$
11850 IF Char$=CHR$(255)&"E" THEN GOTO 12050
11860 IF Char$=CHR$(255)&"B" THEN
11870 ON ERROR GOTO 11890
11880 Temp$=Temp$[1,LEN(Temp$)-1]
11890 OFF ERROR
11900 GOTO 12030
11910 END IF
11920 IF Char$=CHR$(255)&"^" THEN
11930 Temp$=""
11940 DISP Temp$
11950 GOTO Up
11960 END IF
11970 IF Char$=CHR$(255)&"V" THEN
11980 Temp$=""
11990 DISP Temp$
12000 GOTO Down
12010 END IF
12020 Temp$=Temp$&Char$
12030 DISP Temp$
12040 GOTO 11820
12050 OFF KBD
12060 Value$(I)=Temp$
12070 Temp$=""
12080 Where$=""
12090 !*****
12100 !** VALID ENTRY CHECK ROUTINE **

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```

12110 !*****
12120 !
12130 !*****
12140 !** IF THE ENTRY IS SUPPOSED TO BE A NUMBER **
12150 !** CHECK TO SEE THAT IT IS AND STRIP OFF **
12160 !** TRAILING TEXT. THEN TEST TO SEE IF THE **
12170 !** NUMBER IS BETWEEN THE SPECIFIED HIGH **
12180 !** AND LOW VALUES. IF ANY OF THESE **
12190 !** CONDITIONS ARE NOT MET THEN REJECT **
12200 !*****
12210 IF N_t$="N" THEN
12220     ON ERROR GOTO 12490
12230     Number=VAL(Value$(I))
12240     OFF ERROR
12250     Value$(I)=VAL$(Number)
12260     IF Number>VAL(High$) THEN
12270         Value$(I)=Erase$
12280         GOTO 12490
12290     END IF
12300     IF Number<VAL(Low$) THEN
12310         Value$(I)=Erase$
12320         GOTO 12490
12330     END IF
12340     ELSE
12350 !*****
12360 !** IF THE ENTRY IS SUPPOSED TO BE TEXT THEN CHECK **
12370 !** TO SEE THAT IT IS ONE OF THE VALID RESPONSES **
12380 !** IF NOT THEN REJECT **
12390 !*****
12400     IF Text1$<>" " THEN GOTO 12430
12410     IF Text2$<>" " THEN GOTO 12430
12420     GOTO 12610
12430     IF Value$(I)=Text1$ THEN GOTO 12610
12440     IF Value$(I)=Text2$ THEN GOTO 12610
12450     Value$(I)=Erase$
12460     GOTO 12490
12470 END IF
12480 GOTO 12610
12490 BEEP 83.1,.2
12500 Temp$=""
12510 DISP Temp$
12520 GOTO 11810
12530 !*****
12540 !** END ENTRY CHECK ROUTINE **
12550 !*****
12560 !
12570 !*****
12580 !** IF THE ENTRY WAS VALID THEN ERASE THE OLD VALUE **
12590 !** AND REPLACE IT WITH THE NEW VALUE **
12600 !*****
12610 PEN -1
12620 LABEL Erase$
12630 PEN 1
12640 MOVE 85,95-5*I
12650 LABEL Value$(I)
12660 GOTO Diddle_loop
12670 !*****
12680 !** END OF TAKE DATA ROUTINE **

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12690 !*****
12700 !
12710 !*****
12720 !** EXIT ROUTINE BEGINS HERE **
12730 !*****
12740 Done: !
12750 !*****
12760 !** ERASE THE CURSOR FROM ITS PRESENT LOCATION **
12770 !*****
12780     MOVE 5,95-5*I
12790     PEN -1
12800     LABEL Cursor$
12810     PEN 1
12820 !*****
12830 !** THIS FOR NEXT LOOP TESTS FOR ANY MISSING **
12840 !** ENTRIES. IF ANY ARE FOUND THEN THE EXIT **
12850 !** IS IGNORED UNTIL ALL ASKED FOR VALUES **
12860 !** ARE ENTERED **
12870 !*****
12880 OFF KBD
12890     FOR K=0 TO Num_of_choices-2
12900     IF Value$(K)="" THEN
12910         MOVE 5,95-5*K
12920         LABEL Cursor$
12930         I=K
12940         Where$=""
12950         GOTO 11490
12960     END IF
12970     NEXT K
12980     CLEAR SCREEN
12990 !*****
13000 !** END OF EXIT ROUTINE **
13010 !*****
13020 !*****
13030 !** IF THIS POINT IS REACHED THEN THE SUBPROGRAM **
13040 !** IS EXITED **
13050 !*****
13060 GOTO 13620
13070 !*****
13080 !** STRING EXTRACTION SUB-ROUTINE **
13090 !*****
13100 !** THIS ROUTINE EXTRACTS THE INFORMATION **
13110 !** FROM THE CONSTRAINTS$ STRING AND PLACES **
13120 !** IT IN A SERIES OF STRINGS THAT CAN BE USED **
13130 !** TO TEST THE ENTERED VALUE$ STRING TO SEE **
13140 !** IF IT IS VALID **
13150 !*****
13160 Extract: !
13170 N_t$=""
13180 High$=""
13190 Low$=""
13200 Text1$=""
13210 Text2$=""
13220 T$=""
13230 P=1
13240 K$=""
13250 T$=Constraints$(I)[P,P]
13260 IF T$=", " THEN GOTO Next_string

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```

13270 IF T$="!" THEN GOTO Finish
13280 K$=K$&T$
13290 P=P+1
13300 GOTO 13250
13310 Next_string:~
13320 IF N_t$="" THEN
13330     N_t$=K$
13340     P=P+1
13350     GOTO 13240
13360 END IF
13370 IF High$="" THEN
13380     High$=K$
13390     P=P+1
13400     GOTO 13240
13410 END IF
13420 IF Low$="" THEN
13430     Low$=K$
13440     P=P+1
13450     GOTO 13240
13460 END IF
13470 IF Text1$="" THEN
13480     Text1$=K$
13490     P=P+1
13500     GOTO 13240
13510 END IF
13520 IF Text2$="" THEN
13530     Text2$=K$
13540     P=P+1
13550     GOTO 13240
13560 END IF
13570 Finish:~
13580     RETURN
13590!*****~
13600!** END OF THE STRING EXTRACTION SUB-ROUTINE **
13610!*****~
13620 SUBEND
13630 ~
13640 !*****~
13650 !** DATA ARRAY CONVERTER AND STORAGE SUBROUTINE **
13660 !*****~
13670 ~
13680 SUB Data_converter(Datums(*),Filename$)
13690 DIM Build_string$(1000)
13700 Build_string$=""
13710 Dimen=RANK(Datums)
13720 IF Dimen<>2 THEN Finish
13730 Row_lower_bound=BASE(Datums,1)
13740 Row_upper_bound=BASE(Datums,1)+SIZE(Datums,1)-1
13750 Col_lower_bound=BASE(Datums,2)
13760 Col_upper_bound=BASE(Datums,2)+SIZE(Datums,2)-1
13770 CREATE Filename$,1
13780 ASSIGN @File_path TO Filename$;FORMAT ON
13790 !*****~
13800 !** BUILD THE DATA COLUMN HEADINGS **
13810 !*****~
13820 Build_string$="Stage Position"&CHR$(9)&"Exit Prism"&CHR$(9)&"Meas
Prism"&CHR$(9)&"Cell 1"&CHR$(9)&"Cell 2"&CHR$(9)&"Cell 3"&CHR$(9)

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13830 Build_string$=Build_string$&"Exit
Quiescent "&CHR$(9)&"Loss"&CHR$(9)&"Log(Loss)"&CHR$(10)
13840 FOR J=Row_lower_bound TO Row_upper_bound STEP 1
13850 FOR I=Col_lower_bound TO Col_upper_bound-1 STEP 1
13860 Build_string$=Build_string$&VAL$(Datums(J,I))&CHR$(9)
13870 NEXT I
13880 Build_string$=Build_string$&VAL$(Datums(J,I))&CHR$(10)
13890 OUTPUT @File_path USING "#,K";Build_string$
13900 Build_string$=""
13910 NEXT J
13920 ASSIGN @File_path TO *
13930 GOTO 13970
13940 Finish:
13950         BEEP 1708.98,1
13960         DISP "YOUR DATA ARRAY IS NOT TWO DIMENSIONAL"
13970 SUBEND
13980 !
13990 !*****
14000 !** END OF DATA CONVERTER SUBROUTINE **
14010 !*****
14020 SUB
Hurst(Num_of_choices,Choices$(*),Steps$(*),@Multi,@Voltmeter,Initial_steps,
Pressure2)
14030 !
14040 !*****
14050 !** THIS SUBPROGRAM ALLOWS MENU-LIKE CONTROL OF THE HURST **
14060 !** MOTOR CONTROLLER THAT DRIVES THE MEASUREMENT ARM. **
14070 !** THIS IS DONE TO INITIALIZE THE POSITION OF THE PRISM **
14080 !** AND TO DETERMINE THE COUPLING PRESSURE FOR THE RUN **
14090 !*****
14100 !
14110 !** VARIABLE DESCRIPTIONS: **
14120 !** **
14130 !** Num_of_choices - THIS IS THE TOTAL NUMBER OF ITEMS **
14140 !** LISTED IN THE MENU ON THE SCREEN **
14150 !
14160 !** Choices$(*) - THIS IS A SERIES OF STRINGS CONTAINING **
14170 !** THE TEXT ASKING FOR INPUT INFORMATION **
14180 !** e.g. "1000 STEPS" **
14190 !** OPTION BASE 0 MUST BE USED e.g. WHEN **
14200 !** Num_of_choices=3 then Choices$(*) MUST **
14210 !** BE NUMBERED Choices$(0),Choices$(1),AND **
14220 !** Choices$(2) **
14230 !** **
14240 !** Steps$(*) - THIS SET OF STRINGS CONTAINS THE **
14250 !** NUMBER OF STEPS THAT WILL BE MOVED **
14260 !** WHEN THE LEFT OR RIGHT ARROW KEY IS **
14270 !** PRESSED **
14280 !** **
14290 !** @MULTI - THIS IS THE HPIB ADDRESS OF THE **
14300 !** MULTIPROGRAMMER. THIS IS ASSIGNED AT THE **
14310 !** BEGINNING OF THE PROGRAM **
14320 !** **
14330 !** @VOLTMETER - THIS IS THE HPIB ADDRESS OF THE HP3457A **
14340 !** VOLTMETER. THIS IS ASSIGNED AT THE **
14350 !** BEGINNING OF THE PROGRAM **
14360 !** **
14370 !** Initial_steps - THIS IS THE TOTAL NUMBER OF STEPS **

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14380 !**                                THAT THE MOTOR HAS ROTATED SINCE THE **
14390 !**                                MANUAL POSITIONING OF THE PRISM BEGAN **
14400 !**                                AFTER THE FINAL PRESSURE IS DETERMINED **
14410 !**                                BY THE USER THIS NUMBER IS USED AS A **
14420 !**                                BASE REFERENCE FOR THE AUTOMATED **
14430 !**                                MEASUREMENTS **
14440 !**                                **
14450 !*****
14460 !
14470 !*****
14480 !** SETUP VOLTMETER TO READ THE MEASUREMENT PRISM **
14490 !*****
14500 !
14510 OUTPUT @Voltmeter;"TERM REAR"
14520 OUTPUT @Voltmeter;"CHAN 1"
14530 !
14540 !*****
14550 !** THE NEXT 4 LINES CLEAR THE SCREEN,SET THE STARTING **
14560 !** POINT FOR LABELS,SET THE PEN TO WRITE AND SET THE **
14570 !** CHARACTER SIZE **
14580 !*****
14590 !
14600 CLEAR SCREEN
14610 PEN 1
14620 CSIZE 4,.5
14630 !
14640 !*****
14650 !** THIS LINE MAKES THE CHOOSING CURSOR A WHITE BLOCK **
14660 !*****
14670 !
14680 Cursor$=CHR$(127)
14690 !
14700 !*****
14710 !** THE FOR NEXT LOOP PUTS THE CHOICES ON THE SCREEN **
14720 !*****
14730 !
14740 FOR I=0 TO Num_of_choices-1
14750 MOVE 10,95-5*I
14760 LABEL Choices$(I)
14770 NEXT I
14780 !
14790 !*****
14800 !** THE NEXT 3 LINES PLACES THE CURSOR BESIDE THE 1st CHOICE **
14810 !*****
14820 !
14830 MOVE 5,95
14840 I=0
14850 LABEL Cursor$
14860 !
14870 !*****
14880 !** THE NEXT 4 LINES PRINT THE TOTAL NUMBER OF STEPS TAKEN **
14890 !** AND THE CURRENT PRISM PRESSURE **
14900 !*****
14910 !
14920 ENTER @Voltmeter;Pressure2 !GET CURRENT PRISM PRESSURE
14930 MOVE 10,20
14940 LABEL "THE TOTAL NUMBER OF STEPS TAKEN IS ";Initial_steps
14950 LABEL "THE PRISM PRESSURE IS ";VAL$(Pressure2*10)&" Lbs"

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14960 !
14970 !*****
14980 !** THE NEXT 4 LINES PRINTS AN OPERATING INSTRUCTION ON THE SCREEN **
14990 !*****
15000 !
15010 MOVE 10,30
15020 LABEL "PRESS RETURN WHEN MANUAL ADJUSTMENT IS COMPLETE"
15030 MOVE 10,35
15040 LABEL "USE LEFT/RIGHT ARROWS TO MOVE MOTOR (Left=Up, Right=Down)"
15050 MOVE 10,40
15060 LABEL "USE UP/DOWN ARROWS TO SCROLL MENU"
15070 !
15080 !*****
15090 !** WHEN A KEY IS STRUCK GO TO THE MOVE CURSOR ROUTINE **
15100 !*****
15110 !
15120 Diddle_loop: ON KBD GOTO Movement
15130         PEN -1
15140         MOVE 10,20
15150         LABEL
15160         LABEL "                ";VAL$(Pressure2*10)&" Lbs"
15170         PEN 1
15180         ENTER @Voltmeter;Pressure2
15190         MOVE 10,20
15200         LABEL "
15210         LABEL "                ";VAL$(Pressure2*10)&" Lbs"
15220         GOTO 15130
15230 !
15240 !*****
15250 !** MOVE CURSOR ROUTINE **
15260 !*****
15270 !
15280 !*****
15290 !** THIS ROUTINE ONLY TAKES ACTION WHEN THE UP,DOWN OR **
15300 !** RETURN KEY IS PRESSED. GO TO Up ON UP KEY, GO TO **
15310 !** Down ON DOWN KEY, GO TO Take_data ON RETURN **
15320 !*****
15330 !
15340 Movement: !
15350         Where$=KBD$
15360         OFF KBD
15370         IF Where$=CHR$(255)&"^" THEN Up
15380         IF Where$=CHR$(255)&"V" THEN Down
15390         IF Where$=CHR$(255)&"<" THEN Move_arm_up
15400         IF Where$=CHR$(255)&">" THEN Move_arm_down
15410         IF Where$=CHR$(255)&"E" THEN Finished
15420 GOTO Diddle_loop
15430 !
15440 !*****
15450 !** END OF MOVE CURSOR ROUTINE **
15460 !*****
15470 !
15480 !*****
15490 !** UP MOVEMENT ROUTINE **
15500 !*****
15510 !
15520 !*****
15530 !** THIS SCROLLS THE CURSOR UP **

```

```

15540 !*****
15550 !
15560 Up: !
15570 PEN -1
15580 MOVE 5,95-5*I
15590 LABEL Cursor$
15600 IF I=0 THEN
15610         I=Num_of_choices-1
15620         ELSE
15630         I=I-1
15640 END IF
15650 PEN 1
15660 MOVE 5,95-5*I
15670 LABEL Cursor$
15680 GOTO Diddle_loop
15690 !
15700 !*****
15710 !**  END OF UP MOVEMENT ROUTINE  **
15720 !*****
15730 !
15740 !*****
15750 !**  DOWN MOVEMENT ROUTINE  **
15760 !*****
15770 !
15780 !*****
15790 !** THIS SCROLLS THE CURSOR DOWN **
15800 !*****
15810 !
15820 Down: !
15830 PEN -1
15840 MOVE 5,95-5*I
15850 LABEL Cursor$
15860 IF I=Num_of_choices-1 THEN
15870         I=0
15880         ELSE
15890         I=I+1
15900 END IF
15910 PEN 1
15920 MOVE 5,95-5*I
15930 LABEL Cursor$
15940 GOTO Diddle_loop
15950 !
15960 !*****
15970 !**  END OF DOWN MOVEMENT ROUTINE  **
15980 !*****
15990 !
16000 !*****
16010 !** BEGIN STAGE MOVEMENT ROUTINES **
16020 !*****
16030 !
16040 !*****
16050 !** THIS SUBROUTINE MOVES THE MEASUREMENT ARM UP  **
16060 !** BY THE NUM. INDICATED BY THE CURRENT VALUE OF  **
16070 !** Steps$(I).  **
16080 !** THE COMPUTER THEN POLLS THE VOLTMETER TO  **
16090 !** DETERMINE THE NEW PRESSURE ON THE PRISM AND  **
16100 !** PRINTS IT ON THE SCREEN  **
16110 !*****

```

```

16120 !
16130 Move_arm_up: !
16140 !
16150         IF VAL(Steps$(I))>Initial_steps THEN
16160             OUTPUT @Multi;"WF,8.1,0,8.2,5000T,OP,8,-
"&VAL$(Initial_steps)&"T"
16170             WAIT .005*Initial_steps ! WAIT UNTIL FINISHED
16180             ELSE
16190             OUTPUT @Multi;"WF,8.1,0,8.2,5000T,OP,8,-"&Steps$(I)&"T"
16200             WAIT .005*VAL(Steps$(I)) ! WAIT UNTIL FINISHED
16210         END IF
16220 !
16230 !*****
16240 !** CLEAR THE OLD NUMBER OF STEPS FROM THE SCREEN THEN PRINT **
16250 !** THE NEW NUMBER OF STEPS AND CURRENT PRESSURE ON THE SCREEN **
16260 !*****
16270 !
16280         MOVE 10,20
16290         PEN -1
16300         LABEL "                                ";Initial_steps
16310         LABEL "                                ";VAL$(Pressure2*10)&" Lbs"
16320         ENTER @Voltmeter;Pressure2 !GET NEW PRESSURE
16330 !
16340 !*****
16350 !** CALCULATE NEW TOTAL STEPS AFTER MOVE **
16360 !*****
16370 !
16380         IF VAL(Steps$(I))>Initial_steps THEN
16390             Initial_steps=0
16400             ELSE
16410             Initial_steps=Initial_steps-VAL(Steps$(I))
16420         END IF
16430 !
16440 !*****
16450 !** LABEL NEW VALUES ON THE SCREEN **
16460 !*****
16470 !
16480         MOVE 10,20
16490         PEN 1
16500         LABEL "                                ";Initial_steps
16510         LABEL "                                ";VAL$(Pressure2*10)&" Lbs"
16520         GOTO Diddle_loop
16530 !
16540 !*****
16550 !** THIS SUBROUTINE MOVES THE MEASUREMENT ARM DOWN **
16560 !** BY THE NUM. INDICATED BY THE CURRENT VALUE OF **
16570 !** Steps$(I). **
16580 !** THE COMPUTER THEN POLLS THE VOLTMETER TO **
16590 !** DETERMINE THE NEW PRESSURE ON THE PRISM AND **
16600 !** PRINTS IT ON THE SCREEN **
16610 !*****
16620 !
16630 Move_arm_down: !
16640 !
16650         OUTPUT @Multi;"WF,8.1,0,8.2,5000T,OP,8,"&Steps$(I)&"T"
16660         WAIT .005*VAL(Steps$(I)) ! WAIT UNTIL FINISHED
16670 !
16680 !*****

```



```

16690 !** CLEAR THE OLD NUMBER OF STEPS FROM THE SCREEN THEN PRINT **
16700 !** THE NEW NUMBER OF STEPS AND CURRENT PRESSURE ON THE SCREEN **
16710 !*****
16720 !
16730         MOVE 10,20
16740         PEN -1
16750         LABEL "                               ";Initial_steps
16760         LABEL "                               ";VAL$(Pressure2*10)&" Lbs"
16770         ENTER @Voltmeter;Pressure2 !GET NEW PRESSURE
16780         Initial_steps=Initial_steps+VAL(Steps$(I))
16790         MOVE 10,20
16800         PEN 1
16810         LABEL "                               ";Initial_steps
16820         LABEL "                               ";VAL$(Pressure2*10)&" Lbs"
16830         GOTO Diddle_loop
16840 !
16850 !*****
16860 !** END ARM MOVEMENT ROUTINES **
16870 !*****
16880 !
16890 !*****
16900 !** IF THE RETURN KEY IS PRESSED THE SUBPROGRAM TERMINATES **
16910 !** AND RETURNS THE LAST PRESSURE READING TO THE MAIN PROGRAM **
16920 !*****
16930 !
16940 !*****
16950 !** READ PRISM PRESSURE FOR USE IN MAIN PROGRAM **
16960 !** MOVE PRISM BACK TO HOME POSITION **
16970 !*****
16980 !
16990 Finished:
17000         ENTER @Voltmeter;Pressure2 !GET NEW PRESSURE
17010         OUTPUT @Multi;"WF,8.1,0,8.2,5000T,OP,8,-
"&VAL$(Initial_steps)&"T"
17020         WAIT .005*Initial_steps
17030         CLEAR SCREEN
17040 SUBEND

```